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*Editor*
ROY WALDO MINER

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EUNICE THOMAS MINER

UNIVERSITY OF MICHIGAN

## *SECTION OF GEOLOGY AND MINERALOGY*

### DEVELOPMENT OF THE U.S. NAVY'S ICE FORECASTING SERVICE, 1947-1953, AND ITS GEOLOGICAL IMPLICATIONS*

*By* CHARLES C. BATES, HENRY KAMINSKI, AND A. RUSSELL MOONEY**

During the course of a year, the mineral, ice, covers approximately six per cent of the earth's surface. With temporary snow cover excluded, glacial ice of land origin makes up roughly half of this amount; the remainder is predominantly sea ice covering the Arctic and Antarctic Oceans and neighboring seas. Geologically speaking the study of land ice is well advanced, for many students of the field, such as H. Bader, G. Seligman, R. F. Flint, R. P. Sharpe, and H. W. Ahlmann, to name only a few, continually add important contributions to the fund of available knowledge. In the case of sea ice, however, geological interest has been relatively minor, and this particular realm of knowledge has been chiefly the domain of mariners, meteorologists, and oceanographers. Perhaps this is as it should be, for scientific understanding normally proceeds from an initial stage of observation and experiment through data compilation and analysis to the development of prediction techniques and technological applications. In this respect, available knowledge of certain meteorological and oceanographic parameters applicable to the problems of ice forecasting has permitted the development of prediction techniques almost immediately following the development of adequate techniques for synoptic ice observation. Because of the pressure of events, however, an accompanying lack of thorough data compilation and analysis leaves certain technological "soft spots" to be repaired in the near future if sea ice forecasting is to become truly a science, especially with regard to this marine mineral's physical properties and its behavior under stress. It is in solving certain of these "soft spots" that geological know-how can provide a real service. Before pointing out these potential fields of research, it is desirable to review in some detail the development of important ice forecasting services to date in order to provide the potential investigator with a proper perspective of the over-all problem.

Ice forecasting services presumably date from those provided by the earliest Eskimo "shamans." The oldest of the systematic ice-reporting services, however, was probably that initiated in Denmark and Finland during the 1840's. Another important European ice-reporting network was established for the North Sea and North Atlantic waters as a result of the 1898 International Geographical Congress, which resolved that the Danish Meteorological Institute should be adopted as the central office for the collection and preparation of information concerning the state of ice in the northern seas. During World War II, the German Ice Service maintained a synoptic ice observation network extending eastward as far as the Black Sea and northward to the edge of the Arctic Ocean, through the use of aircraft and submarines. Boehnecke[1] reports the German Ice Service operating as follows during this period:

"With daily ice charts of the North, Baltic, and Black Seas available, weekly charts of the Polar Sea, the weather map, and the synoptic oceanographic chart of the sea area in question, it issued regular ice predictions. For the southern Baltic, both short range (1- to 3-day) and long range (5-

*This paper, illustrated with color motion pictures, was presented at a meeting of the Section on January 4, 1954.

**Division of Oceanography, U. S. Navy Hydrographic Office, Washington, D. C. The opinions expressed in this paper are those of the authors as individuals and are not to be construed as necessarily reflecting the official views of the Navy Department.

to 10-day) forecasts were issued, beginning in 1942-1943, which proved 80 per cent accurate."

Palosuo's (1953) treatise on Finnish ice observations, particularly during World War II, should also be noted by the reader wishing to investigate the subject further.

The ice forecasting service most important to a nation's economy has been that conducted by the U.S.S.R. Armstrong's extensive analysis of the Northern Sea Route[1] indicates that the first Russian ice forecast was issued in 1923 for conditions during the coming summer in the Barents Sea. In 1932, forecasts were issued for the first time for all five seas making up the route. By 1938, all work on long-range ice forecasts was concentrated in the Arctic Institute. These forecasts were made four times a year: in December, to give a trend indication of expected conditions during the next summer; in February, to outline more exactly the December forecast; in May, to provide a forecast on which navigation could actually be planned; and in August to predict closing dates for shipping. The long-range forecasts were made from headquarters in Moscow and Leningrad, while short-term forecasts of 5- to 10-days were made from polar stations and from icebreakers on which shipping movements were being tactically directed. These forecasts were based on extensive aerial reconnaissance. The number of hours flown on this type of mission increased from 200 in 1933 to 2900 in 1944. Aerial reconnaissance was further augmented between 1938 and 1944 by small patrol vessels which yearly cruised the southern edge of the consolidated pack reporting its location. In Armstrong's opinion, the forecasts were in their infancy during the 1930's and lacked essential observational data. By 1939, short-term forecasts were stated to be correct as follows: Kara Sea, 70 per cent; Laptev Sea, 65 per cent; and Chukchi Sea, 85 per cent, where the scale of 100 per cent is completely correct, 50 per cent partially correct, and 0 per cent totally erroneous. In 1940, long-term forecasts for the Kara Sea were said to be 75 per cent correct.

The importance of the Soviet Union's ice program can best be indicated by results of the 1937 season when, in order to execute several spectacular expeditions to and over the North Pole, the Soviets left only two aircraft for ice reconnaissance along the Northern Sea Route. Unreliable ice and weather forecasts resulting therefrom were among the chief factors considered responsible for 26 ships wintering in ice, including seven of the eight serviceable icebreakers of the Chief Administration of the Northern Sea Route. As a result of this misfortune, increased emphasis was placed on the study of ice, hydrographic, and oceanographic conditions along the route, while geological aspects of this northern area were de-emphasized. By 1946, aerial reconnaissance techniques were standardized sufficiently to permit the preparation of an excellent 132 page text on the subject, *Ledovaia Aviatsionnaia Razvedka (Aerial Ice Reconnaissance.)*[3] It can be expected that similar attention is being paid to forecasting problems, although texts are not available in the western world.

The most famous organization for ice prediction is undoubtedly the International Service for Ice Observation and Ice Patrol, established by international agreement in 1913 following the *Titanic* disaster. Still one of the world's most efficient ventures in the field of international cooperation, the Service is financed by participating countries on a share basis. The International Ice Patrol proper is operated by the U.S. Coast Guard, and additional data on iceberg location and surface water temperatures are supplied by the several hundred cooperating ships crossing the North Atlantic Ocean along the Great Circle Route. The

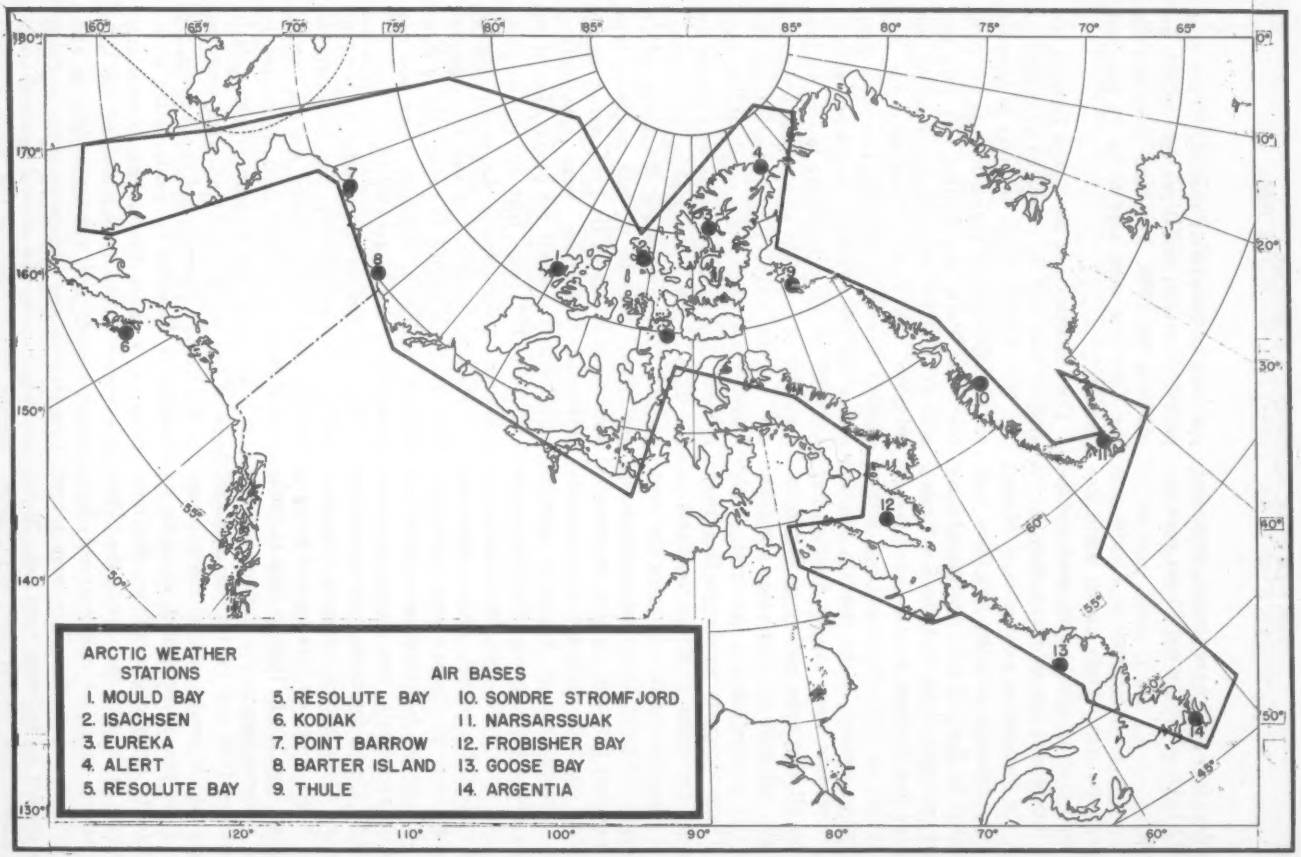



FIGURE 1. Location of 1953 ice reconnaissance areas, aircraft bases, and Arctic weather stations.

basic mission for this service has been little changed since its inception and may be stated to be: "....To guard the southeastern, southern and southwestern limits of regions of icebergs in the vicinity of the Grand Banks of Newfoundland for the purpose of informing trans-Atlantic and other passing vessels of the extent of this dangerous region; to observe and study ice conditions in general; to destroy or remove derelicts; and to afford assistance to vessels and crews requiring aid within the limits of operation of the patrol vessels."[11]

The Patrol's effort has been primarily centered on the region of the Grand Banks of Newfoundland. However, Coast Guard cutters have investigated ice and oceanographic conditions in the Davis Strait-Baffin Bay region in 1928, 1931, 1933, 1934, 1935, and 1940. Coast Guard planes were also used in this area in 1948 and 1949, all for the purpose of obtaining a better concept concerning the mechanism whereby icebergs, calved from West Greenland glaciers, eventually reach the open Atlantic shipping areas. During World War II, the Ice Patrol operated out of the Argentia Naval Operating Base in Newfoundland and extended its coverage to as far north as Hudson Strait and as far east as southern Greenland and Iceland. Today, forecasting techniques of the Patrol remain primarily short-range and oceanographic in nature, being restricted to determining the trajectories of floating land and pack ice.

In 1947, the fledgling Division of Oceanography of the U.S. Navy Hydrographic Office began a study of ice in the sea, particularly in the American Arctic; for it was considered that this neglected aspect of the ocean was the most susceptible of any to solution by a moderate expenditure of two or three man-years of study per annum. Accordingly, oceanographers from the Hydrographic Office and civilian institutions were assigned to accompany naval cruises to the Canadian Archipelago and to Point Barrow; work was started on an official glossary of ice terminology, a manual of ice seamanship, and an ice mechanics field test kit; on development of shipboard and aerial observing and reporting techniques, and on the utilization of the Arctic Research Laboratory at Point Barrow, Alaska for ice studies. Results of the preliminary work through early 1949 have been published by Bates and Lill.[1] Subsequently, the manuals, *Ice Seamanship*[9] and the *Glossary of Ice Terminology*[10] were published by the U. S. Navy Hydrographic Office; the Frost Effects Laboratory of the Corps of Engineers tested a prototype model of the ice mechanics kit which permitted determination of ice thickness, density, salinity, temperature, and behavior under stress from shear, tension, and compression;[7] and track charts utilizing a standard ice symbolization were found to be better for regional coverage than numerical ice codes used by shipboard observers and those stationed at specific shore locations.

Until 1950, ice reconnaissance for naval purposes in the American Arctic had been primarily the responsibility of task force or ship commanders who, with only masthead or helicopter observation available, believed that "ice is where you find it." Although essential for immediate operational requirements, this method of obtaining ice information was considered inadequate for extensive or large-scale operations of surface units. Hence, in order to provide better information for tactical planning during resupply of the jointly operated United States-Canadian weather stations in the Canadian Archipelago (see FIGURE 1), the Canadian government offered to supply two Lancaster aircraft and flight crews during the 1950 season for Operation NANOOK-1950 if the United States would supply competent aerial ice observers. The Hydrographic Office supplied M. Schefer, and the U. S. Weather Bureau, Col. Charles Hubbard, Head of its Arctic Section, until the latter

U. S. NAVY HYDROGRAPHIC OFFICE

SHIP ICE LOG

TABLES

TABLE 1. Concentration: total and by type.

TABLE 2. Ridged and Ice Thickness

TABLE 3. Topography

TABLE 4. Age or ar[illegible]

TABLE 5. Puddling

TABLE 6. Snow cover

TABLE 7. Water features

TABLE 8. Orientation of water features

TABLE 9. Floe ice

TABLE 10. Ice of land origin

TABLE 11. Visibility and Dimension

TABLE 12. Water sky and Iceblink

Instructions for use of ice log are found at back of pad.

Concentration, total
Concentration, each type
Ridged ice
Topography
Age, snow ice
Age, snowdrift
Puddling
Snow cover
Floe features
Orientation of water features
Floe ice
Ice of land origin
Thickness new ice
Visibility
Water sky
Iceblink
Water temp. °F

TABLE 1 1 1 1 1 2 3 4 4 5 6 7 8 9 10 2 11 12 12

FIGURE 2. U. S. Navy Hydrographic Office ship ice log.

was killed in a crash at Station ALERT in northern Ellesmere Land in August, 1950. Results of this aerial ice reconnaissance were sufficiently encouraging to indicate the desirability of conducting much the same type of operation during the 1951 season.

Hydrographic Office observers first flew in 1951 in support of Operation BLUEJAY aboard regularly scheduled aircraft of the Military Air Transport Service en route to and from the embryo Thule Air Force Base. Pick has described this supply operation in detail, the largest Arctic venture thus far conducted by the United States.[6] In 1951, there were no ice forecasts available, and on the basis of climatic information, engineer troops and highly paid civilian

| ICE FEATURE | METHOD OF RECORDING SYMBOLS | EXPLANATION OF TERMS AND EXAMPLES |
|---|---|---|
| Concentration of Sea Ice by Size | $\frac{Cn}{n_1\ n_2\ n_3}$<br>where:<br>Cn = feature (concentration),<br>$n_1 + n_2 + n_3$ = total concentration,<br>and $n_1$ = tenths of slush, brash, and block,<br>$n_2$ = tenths of small and medium floes,<br>$n_3$ = tenths of giant floes and fields. | Examples: $\frac{Cn}{432}$ = a total concentration of nine-tenths of which four-tenths are slush, brash, and block; three-tenths are small and medium floes; and two-tenths are giant floes and fields.<br>$\frac{Cn}{0010}$ = a total concentration of ten-tenths consisting exclusively of giant floes and fields. |
| Topography | pressure ice ^^^^ | The single symbol will be entered to show the presence of rafted, ridged, or hummocked ice. |
| Color | $\frac{Cl}{We,\ Bk,\ Be,\ Gy,\ Gn}$<br>where:<br>Cl = color, Be = blue,<br>We = white, Gy = gray,<br>Bk = black, Gn = green. | All ice colors will be entered in order of decreasing area. Generally speaking white will be first. Cloud shadows on otherwise white ice will not be entered as gray. |
| Puddles | $\frac{Pd}{n\ or\ F}$<br>where:<br>Pd = puddles,<br>n = tenths of ice area covered,<br>F = frozen. | Puddles do not usually exceed eight-tenths. No entry will be made if puddles are absent. |
| Snow Cover | where: $\frac{Sn}{D\ or\ O}$<br>Sn = snow,<br>D = drifted,<br>O = no snow. | Unless the snow is conspicuously drifted or practically absent, no entry will be made. |
| Water Features | Crack, Lead, Polynya — Orient geographically | With total concentrations of five-tenths or less, these data need not be entered.<br>With total concentrations of eight-tenths or less, but with uniform ice distribution, i.e. water features of random orientation, these data need not be entered.<br>Width of leads should be entered in miles or yards at points of greatest constriction and divergence, as: ½ mi. 4 mi. |
| Ice of Land Origin | Many Few<br>Icebergs ▲ △<br>Bergy bits and Growlers ▬ ▱ | Within the field of view, 20 or more icebergs will be considered many; less, few.<br>Within the field of view, 100 or more bergy bits and growlers will be considered many; less, few. |
| UNDERCAST | Limits | The first symbol will be placed at the entrance to the undercast or fog area, the last upon emergence. This symbol also may be used to indicate the boundary of cloud decks on either beam. |

FIGURE 3. U. S. Navy Hydrographic Office's instructions for aerially logging ice conditions.

contractor personnel were loaded early and kept at sea at great expense for several weeks before transit of the Baffin Bay Pack was negotiated. During this same period, the quality of aerial ice reconnaissance was necessarily poor, since MATS planes flew at normal flight altitudes of about 9,000 feet, and observations were confined to regularly established flight routes preventing adequate coverage of the sea area within which the operation was conducted. In addition, frequent undercast made ice observation extremely spotty. Not until aircraft were later assigned exclusively to aerial reconnaissance permitting greater coverage at low levels was it possible to locate suitable passages in the ice through which convoys were safely escorted to Thule. Moreover, since planes could not be diverted from their normal tracks, it proved impossible to obtain a complete picture of ice coverage over the entire Baffin Bay re-

gion for investigating the problems related to the forecasting of sea ice. Later in the season, the aerial reconnaissance by the same Hydrographic Office observers utilizing Canadian aircraft assigned on full-time basis over the Canadian Archipelago provided a better advisory service for NANOOK-1951 than had been obtained for the much more important Operation BLUE-JAY.

Accordingly, with ice damage to Military Sea Transport Service shipping amounting to many millions of dollars for the 1951 season alone, this cost-conscious, corporation-like service requested the Hydrographer of the Navy to expand the 1952 Navy's ice-observation service over the Labrador Sea-Davis Strait-Baffin Bay area and, if possible, to issue tentative long- and short-range ice forecasts for the region. The first long-range forecast of expected ice conditions in the Labrador area was accordingly prepared in March 1952 for the coming shipping season based on historical ice data, climatology, and evaluation of preliminary ice surveys in this area. Starting in May 1952, P4Y2 aircraft of Naval Patrol Squadron 23 were made available for expanded coverage of the Labrador Sea-Davis Strait-Baffin Bay area for the ensuing shipping season, whereas the summer reconnaissance of the Canadian Arctic was again to be conducted, utilizing Lancaster aircraft of Canada's 404 Maritime Squadron. This combined effort resulted in 875 hours being flown between May and October, 1953

HYDROGRAPHIC OFFICE ICE RECONNAISSANCE MESSAGE

"ICE 2 JULY 53. THULE TO ... TO THULE, ALTITUDE 300 (FEET) VISIBILITY 5 TO 10 MILES. NORTH STAR BAY 260 EIGHT, PUDDLED. WEST OF SAUNDERS AND KAP ATHOLL LESS THAN 1/10. BOUNDARY OF SHORELEAD, KAP ATHOLL TO KAP YORK 7615N 6935W TO ... TO ... , MANY BERGS VICINITY CONICAL ROCK. NORTH LIMIT OF LEAD MELVILLE BAY FROM KAP YORK TO BUSHMANS TO ... TO ... , SOUTH LIMIT ... TO ... . UNDERCAST TO BRYANTS. CONCENTRATION BRYANTS TO THOM 233 EIGHT TO 313 SEVEN 15 MILES OFF KAP SEDDON TO 220 FOUR TO 110 TWO FIVE MILES OFF DEVILS THUMB. ONE MILE WIDE LEAD 7527N 5900W TO ... NARROWING TO 50 YARDS AT ... TO ... . OUTER LIMIT LANDFAST ICE 7505N 5815W TO ... NORTHABOUT ROUTE DIFFICULT TO TRANSIT FROM 10 MILES SOUTH OF THOM TO 5 MILES WEST OF BRYANTS, LESS ICE TO PENETRATE THIS ROUTE THAN UPPER MIDDLE PASSAGE. MOONEY HYDRO REP AND SENAV PATRON TWO THREE SEND. END"

U.S.S.R. ICE MESSAGE

"PLANE N-308, AUGUST 9, 1943, TAKE-OFF 0215, LANDING 1145, ALTITUDE 800 (METERS), VISIBILITY 6 TO 10 KM, LOCAL FOG, COURSE 6855 18035 - 6917 17917 ... EASTERN BOUNDARY OF FINELY BROKEN UP ICE 1 POINT, POINTS OF DISRUPTION 5, EVERYTHING TO EAST BEING CLEAR. SOUTHERN BOUNDARY OF SAME ICE 7021 16752 ... EVERYTHING TO S BEING CLEAR. FROM ... FINELY BROKEN ICE 2 POINTS, DISRUPTION 3 TO 4, IN NORTHERN AREA UNEVENLY BROKEN ICE, OCCASIONAL FIELDS. AT THE POINT ... WE CROSSED A 10 POINTS BOUNDARY RUNNING NW TO SE, FURTHER TO ... UNEVENLY BROKEN, FIELD FRAGMENTS 9 POINTS, RIDGING 5 POINTS DISORDERLY, DISRUPTION 3, SEVERAL-YEAR-OLD IMPURE ICE DOMINATES. FURTHER TO ... ZONE OF LESSER DENSITY 2 TO 3 POINTS, RUNNING FROM E TO W. FURTHER TO ... 9 TO 8 POINTS RIDGING 4. CROSSED THE E PART OF A MASS OF 9 TO 10 POINTS WITH NUMEROUS LANES AND SPOTS OF DECREASING DENSITY; EASTERNMOST POINT OF MASS, WE THINK, NOT FURTHER THAN 7130 17000. ICE RECONNAISSANCE GROUP 15."

USAF ICE MESSAGE

"ICE REPORT 5 NOV 1953. FLIGHT EIELSON TO BARTER TO ... TO ... TO BARROW TO EIELSON. ICE PACK ON SHORE AT BARTER. AT ... CONCENTRATION ZERO NINE ONE TOTAL TEN. LEAD ORIENTATED NW SE ONE HALF MILE WIDE FROM ... TO ... . AT ... NUMEROUS SMALL CRACKS BY RADAR. END OF ICE MESSAGE BECAUSE OF DARKNESS AND POOR RADAR RETURN. FM COMDR 58TH STRAT RECN SQ EIELSON AFB ALASKA"

FIGURE 4. Comparison of ice summary messages filed by the U.S.S.R., U. S. Air Force, and U. S. Navy.

in contrast to the 468 hours flown in 1951, two-thirds of which had been from aircraft on routine transport missions. The improved aerial coverage and an increase in daily ice messages from naval surface vessels made it possible to construct a master plot of synoptic ice conditions throughout these waters for the first time. By using this plot and weather forecasts issued by the Fleet Weather Central, Washington, D. C., it became possible for meteorological oceanographers of the Hydrographic Office to issue their first tentative short-range forecasts with regards to ice concentration, lead orientation, and location of ice boundaries.

By the end of the 1952 shipping season, it was feasible to standardize ice observation and reporting techniques. Results of this standardization included Navy Training film 7419B, "Identification of Sea Ice;"

FIGURE 5. Distribution of drift ice in Eastern Canadian and Greenland waters during 18-25 April 1953.

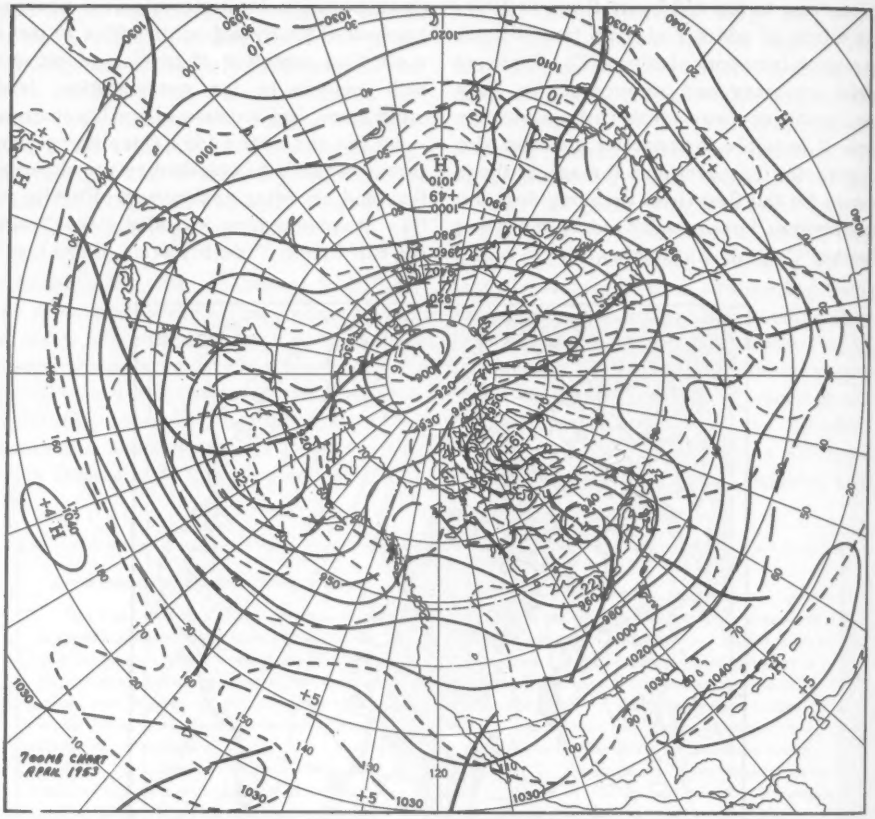



FIGURE 6. Mean 700-millibar pressure chart for the Northern Hemisphere during April, 1953 (courtesy U.S. Weather Bureau).

a detailed ice code for shipboard observers (FIGURE 2); logging instructions for aerial observers (FIGURE 3); and summary ice messages according to a fixed style (FIGURE 4). Radio facsimile transmission of regional charts portraying observed or forecasted ice conditions according to the symbolization of FIGURE 3 also became possible.

Following one of the warmest winters on record in the American Arctic, H. Kaminski and E. Nadeau opened the 1953 ice reconnaissance season in March utilizing P4Y2 aircraft of Naval Patrol Squadron 11. Although the southern boundary of the Labrador Pack was found in about its usual location, the ice cover appeared thinner than usual, and there had been less rafting and pressure ridging of ice. The "North Open Water" was particularly noticeable at this time, for 7,000 square miles of water in northwest Baffin Bay and Smith Sound was covered with 9/10 ice, 70 per cent of which was composed of thin black or gray ice, whereas the close pack ice extended 700 miles farther south through Baffin Bay. Collating this aerial evaluation of ice conditions with an analysis of the various

oceanographic and meteorological parameters affecting the development and growth of ice, a forecast for a light ice year was indicated. By early April the ice cover in southern Baffin Bay was breaking up readily under storm action and sweeping south on the Labrador Current in quantities much larger than considered normal (FIGURE 5). As a result of this increased contribution, the drift ice off Resolution Island, Northwest Territories, which is normally expected to be about 40 miles wide at this time of the year, broadened to about 100 miles with a concentration of from 9/10 to 10/10. A pronounced atmospheric high pressure area, which persisted over northern Greenland for several weeks, prevented spring storms from penetrating into Baffin Bay and resulted in winds of an easterly component which persisted off Resolution Island throughout this period (FIGURE 6). As a consequence, drift ice, compressed against the coast of southeast Baffin Island and the northern Labrador Coast, maintained a heavy concentration and gradually narrowed shoreward, so that by early May this belt of ice was constricted locally to within 7 miles of shore. Although the ice was well broken, generally comprised of block, and small to medium floes, with hummocked remnants well over 10 feet thick, the persistent heavy concentration of practically ten-tenths coverage severely handicapped even a WIND-class icebreaker in transiting this band. Moreover, the abnormal flushing of the ice from the Baffin Bay area southward on the cold waters of the Labrador Current permitted the pack ice to extend in strength south of St. Johns, Newfoundland and hampered traffic in and out of this port for the first time in 72 years (Fiske, personal communication, 1953).

Of equal interest is the warm water penetrating northward along western Greenland which maintains a large ice-free tongue along that coast. It is interesting to note that the present climatic warming is permitting the development of an extensive cod fishery in these waters so that the value of this marine product now exceeds that of the seal fishery. As an indication of this expanding industry there are now established in Greenland 150 fishing stations. Since 1948 the world's largest individual shrimp grounds have also been opened along the western coast in Disko Bay, 600 statute miles north of the latitude of Greenland's southern tip.[8] To assist these greatly increased fishing activities, in late 1953 the Hydrographic Office began supplying, through official channels, its daily ice summaries to the British trawling fleet.

During the summer of 1953, the ice observing and forecasting program was relatively standardized; however, it was on a much larger scale than heretofore as the area of interest broadened to include northern Alaska and the western Canadian Arctic. In this new area, a "bad" ice year was observed (FIGURE 7) in contrast to the favorable conditions observed in the Eastern American Arctic and already mentioned above. Visual reconnaissance by ice specialists of the Hydrographic Office aboard U. S. Navy, U. S. Coast Guard, Canadian, and bush aircraft (for a total of 1,875 flying hours) provided the basic ice data, supplemented by that of personnel of the U. S. Air Weather Service flying PTARMIGAN missions along the 500-millibar surface at an elevation of about 18,000 feet. In this latter case, radar observations were substituted for visual observations with some success (FIGURE 4). One- to five-day ice forecasts issued from the Experimental Oceanographic Central of the Hydrographic Office at Washington, D. C., and from Kodiak, Alaska, by Hydrographic Office forecasters were presented as an extrapolation of the synoptic ice plot into the future based on the expected degree of storminess, direction and magnitude of wind stress, tidal action, and oceanic current patterns. Thirty-day ice forecasts issued from the

Central were based upon the U. S. Weather Bureau's long-range weather forecast and indicated the trend in changing ice conditions. Seasonal ice forecasts issued up to 150 days in advance by the Central were based on oceanographic and climatic studies and provided comparisons with typical and atypical years of the past.

When forecasting the initial formation of sea ice in autumn, following the reversal of the heat-budget, oceanographic variables are given primary consideration, with meteorological variables subordinated. Russian and Austrian formulas for the heat-loss from a column of water have been notably improved by L. Simpson, O. Lee, H. Kaminski, and E. Calloway of the Hydrographic Office and permit surprisingly accurate predictions for both protected and open waters[4] (FIGURE 8). Such formulas have been put to good use for a number of purposes. For example, recently it was desirable to know the dates at which a number of Labrador harbors would be closed to seaplane and various surface vessel operations and opened to ski-plane operation. Utilizing an SA-16 aircraft of the 6603 Air Base Group, A. R. Mooney of the Hydrographic Office made the necessary oceanographic measurements at these sites during a 12-day interval in early October, 1953. Upon receipt of his data they were analyzed at the Hydrographic Office and initial ice forecasts were prepared within a four-day period by the Experimental Oceanographic Forecast Central. After ice appears, oceanographic controls again lessen, and correlations between ice thickness and cumulative degree-days provide the basic type of winter forecasting.

In summary, it should be noted that the U. S. Navy's ice forecasting program has been primarily devoted to problems of coverage and thickness. One of the major problems remaining in the field is the determination of the causes for "good" and "bad" years along the Alaskan coast. It is not yet certain whether a "bad" year is caused

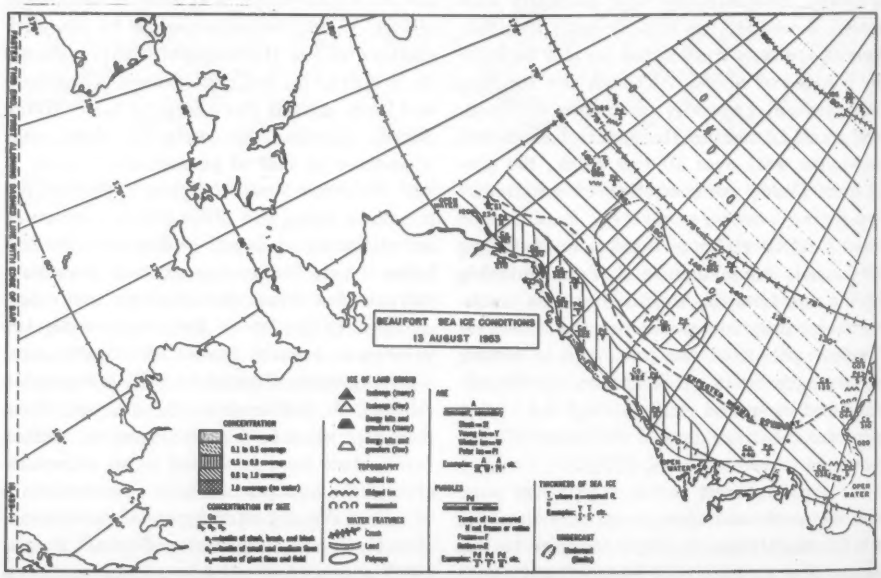


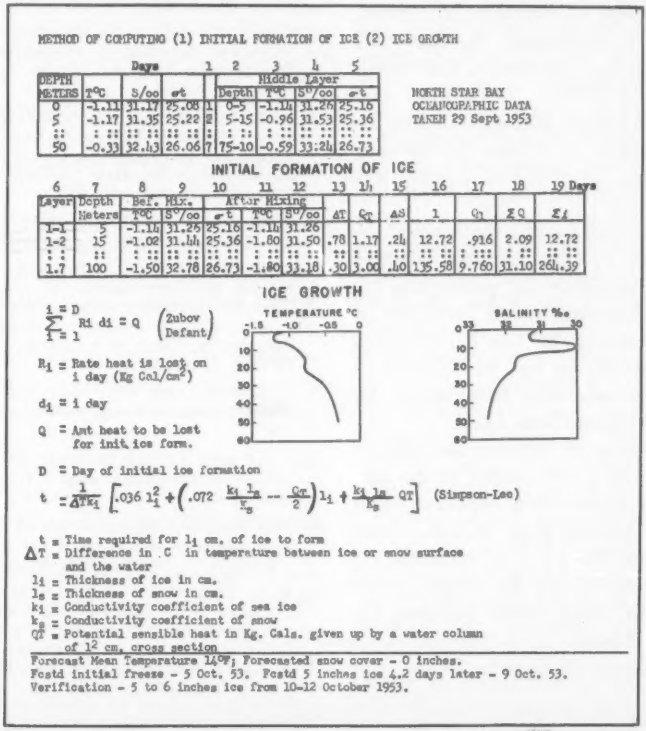

FIGURE 7. Distribution of sea ice in Alaskan waters in August 1953 compared to the approximate boundary of the pack ice at this time during a "good" year.

by failure of the Polar Pack to contract, by failure of the Pack to shift bodily across the Arctic basin, or whether there is less destruction of the Pack's edge than normal. Once problems such as this are solved, the next stage of ice forecasting will presumably be that of strength and type of fracture under various stresses. Such forecasts will require a better knowledge of the physical properties of the sea ice cover in each area than exists today, and observations made with the ice mechanics test kit will presumably come into their own. Similarly, seasonal cycles in crystal structure will also have to be studied in detail. Finally, there remains the strategic problem of determining how persistent the present warming of the Arctic will be. Is another Climatic Optimum in the making like the one five thousand years ago, will it be merely like the lesser warming of a thousand years ago when the Norsemen settled Iceland and Greenland, or is the Northern Hemisphere being subjected to a much shorter cycle of warming than either of those just mentioned? With problems such as these, it is to be anticipated that geological thinking will play an increased part as ice forecasting becomes a science in the near future.

*Acknowledgments*

The chief participants in the U. S. Navy's ice observing and forecasting program described above were as follows:

1948: C. Barnes of the Oceanographic Laboratory, University of Washington; G.



METHOD OF COMPUTING (1) INITIAL FORMATION OF ICE (2) ICE GROWTH

Days 1 2 3 4 5

| DEPTH METERS | T°C | S/oo | σt | | Middle Layer Depth | T°C | S°/oo | σt |
|---|---|---|---|---|---|---|---|---|
| 0 | -1.11 | 31.17 | 25.08 | 1 | 0-5 | -1.14 | 31.26 | 25.16 |
| 5 | -1.17 | 31.35 | 25.22 | 2 | 5-15 | -0.96 | 31.53 | 25.36 |
| :: | : :: | :: :: | :: :: | : | : :: | : :: | :: :: | :: :: |
| 50 | -0.33 | 32.43 | 26.06 | 7 | 75-10 | -0.59 | 33.24 | 26.73 |

NORTH STAR BAY
OCEANOGRAPHIC DATA
TAKEN 29 Sept 1953

INITIAL FORMATION OF ICE

6 7 8 9 10 11 12 13 14 15 16 17 18 19 Days

| Layer | Depth Meters | Bef. Mix. T°C | Bef. Mix. S°/oo | After Mixing σt | After Mixing T°C | After Mixing S°/oo | ΔT | Qr | ΔS | 1 | Q1 | ΣQ | Σ1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1-1 | 5 | -1.14 | 31.26 | 25.16 | -1.14 | 31.26 | | | | | | | |
| 1-2 | 15 | -1.02 | 31.44 | 25.36 | -1.80 | 31.50 | .78 | 1.17 | .24 | 12.72 | .916 | 2.09 | 12.72 |
| : : | :: | : :: | :: :: | :: :: | : :: | :: :: | :: | : :: | :: | :: :: | : ::: | : :: | :: :: |
| 1.7 | 100 | -1.50 | 32.78 | 26.73 | -1.80 | 33.18 | .30 | 3.00 | .40 | 135.58 | 9.760 | 31.10 | 264.39 |

ICE GROWTH

$$\sum_{i=1}^{i=D} R_i\, d_i = Q \quad \begin{pmatrix} \text{Zubov} \\ \text{Defant} \end{pmatrix}$$

$R_i$ = Rate heat is lost on i day (Kg Cal/cm²)

$d_i$ = i day

Q = Amt heat to be lost for init. ice form.

D = Day of initial ice formation

$$t = \frac{1}{\Delta T k_1}\left[.036\, l_1^2 + \left(.072\,\frac{k_1}{k_s}\,l_s - \frac{Q_T}{2}\right) l_1 + \frac{k_1}{k_s}\,l_s\,Q_T\right] \quad \text{(Simpson-Lee)}$$

t = Time required for $l_1$ cm. of ice to form
$\Delta T$ = Difference in °C in temperature between ice or snow surface and the water
$l_1$ = Thickness of ice in cm.
$l_s$ = Thickness of snow in cm.
$k_1$ = Conductivity coefficient of sea ice
$k_s$ = Conductivity coefficient of snow
$Q_T$ = Potential sensible heat in Kg. Cals. given up by a water column of 1² cm. cross section

TEMPERATURE °C
-1.5 -1.0 -0.5 0
0 10 20 30 40 50 60

SALINITY ‰
33 32 31 30
0 10 20 30 40 50 60

Forecast Mean Temperature 14°F; Forecasted snow cover - 0 inches.
Fcstd initial freeze - 5 Oct. 53. Fcstd 5 inches ice 4.2 days later - 9 Oct. 53.
Verification - 5 to 6 inches ice from 10-12 October 1953.

FIGURE 8. Condensed version of the Simpson-Lee calculation used in determining rate of ice formation in North Star Bay, Greenland.

Metcalf of the Woods Hole Oceanographic Institution; and L. P. Allen of the U. S. Navy Hydrographic Office.

1949: G. Metcalf and J. Holmes of the Woods Hole Oceanographic Institution; Major A. R. Gordon, Jr., U. S. A. F. of the Air Weather Service; and C. C. Bates of the U. S. Navy Hydrographic Office.

1950: M. Schefer of the U. S. Navy Hydrographic Office.

1951: H. Kaminski, R. Parker, and M. Schefer of the U. S. Navy Hydrographic Office.

1952: Observers, F. Gaetano, H. Kaminski, R. Parker, and W. Petrie; and forecasters, H. J. Kaminski, F. X. MacDougall, H. F. French, all of the U. S. Navy Hydrographic Office.

1953: Observers, W. Butscher, E. Corton, E. Goldstein, J. Harrington, H. Kaminski, C. Kammer, O. Lee, R. McGough, R. Mooney, E. Nadeau, B. Swanson, J. Tapager, and W. Wittmann; and forecasters, E. Corton, H. Kaminski, J. Ropek, J. Schule, J. Tapager, and W. Wittmann, all of the U. S. Navy Hydrographic Office.

The extensive efforts of Lieutenant Commander L. Fiske, U. S. N., are acknowledged with great appreciation for pioneering the use of ice observations and forecasts in operational planning by the Military Sea Transport Service, as are his efforts in making aircraft available from which the requisite observations were made.

The cooperation of officers and men of various squadrons participating in the program is greatly appreciated, especially that of Commander Donald Wiss, U. S. N., Commanding Officer, Navy Patrol Squadron 11; Commander Victor A. Blandin, U.S.N., Commanding Officer, Navy Patrol Squadron 23; and Squadron Leader O. G. Nelson, R. C. A. F., Detachment Commander, Royal Canadian Air Force 404 (MR) Squadron, without whose interest and enthusiasm the ice program would have been seriously hampered.

On 16 April, 1954 Henry Kaminski, one of the authors of this paper, was killed in the crash of a Navy P4Y2 aircraft on Ellesmere Island during a routine ice reconnaissance flight from Thule AFB, Greenland to Station ALERT on Ellesmere Island.

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# DATING WITH NATURAL RADIOACTIVE CARBON*

*By* DONALD R. CARR AND
J. LAURENCE KULP**

One of the most important scientific discoveries of the past decade is the existence of measurable amounts of carbon 14 in the atmosphere, hydrosphere, and biosphere which has been produced in the upper atmosphere by the reaction of secondary neutrons with $N^{14}$ nuclei. The $C^{14}$ is oxidized and enters the carbon dioxide life cycle of air, water, plants, and animals. Assuming that the cosmic ray flux is essentially constant on the long time scale involved and that mixing is fairly complete in the carbon reservoir, a sample of carbon taken from any part of the carbon cycle should yield a constant concentration of carbon 14. Fractionation effects can cause second order variations. If carbon is removed from the cycle by the death of a plant or animal, the sedimentation of a carbonate or the submergence of surface ocean water, no more carbon 14 is added and the amount present will decay according to the known half-life of 5568 ± 30 years. Therefore, the time of removal from the carbon dioxide life cycle can be measured quantitatively if the carbon 14 concentration is determined. This permits relatively precise age determinations of archeological and geological materials from the present back to several tens of thousands of years ago.

Types of natural materials that are subject to $C^{14}$ determination include plant and animal tissue or decomposition products, air, water, ice, shells, and carbonate or carbonaceous sediments. Each type of sample presents its own problems of contamination and preparation. In the case of air or water, the carbon dioxide is removed by an absorbent in the field at the time of collection. At the laboratory, the samples, therefore, fall into two groups: carbonate and combustible carbon. The carbonates are reacted directly with acid. The combustible material is always leached with hydrochloric acid prior to burning to remove any admixed carbonate.

No matter what the nature of the sample, it should be sufficiently large so that 8 gm. of carbon can be recovered. This requires about 100 gm. of wood or shell, 20-40 gm. of charcoal and 200-300 gm. of peat. Techniques have been developed for counting samples as small as 0.5 gm. of carbon, but considerably more effort is required for a less accurate result.

Fresh wood is the most suitable material, since cellulose does not exchange its carbon to an appreciable extent. Charcoal is generally excellent but, under certain conditions, must be checked for adsorbed organic material. Peat is satisfactory unless contaminated by more recent rootlets. Shell may be used under conditions where the possibility of exchange is low and the isotopic composition of the water in which the animal grew is known. Fresh-water aquatic plants are suspect because they may utilize carbonate carbon from the water, which may have been derived, in part, from old limestone. Burned bone is normally as suitable as charcoal, if enough material can be obtained. Unburned bone has generally lost so much of its organic content by subsequent bacterial action that it is impossible to obtain an adequate sample.

Carbon 14 can be measured in principle by the ion chamber, Geiger counter, proportional counter, or scintillation counter. All the published results to date have been obtained by counting elemental carbon mounted on the inside of a large-volume Geiger tube. Details of the process have been given in papers by Libby,[1] Crane,[2] and Kulp.[3,4,5,6]

The dating procedure consists of prepar-

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ing a sample of pure carbon from the natural carbon-bearing material, mounting this in a special screen-wall Geiger counter, and counting it against background for several days. The key to success is the reduction of the unshielded background of the counter (about 350 c.p.m.) to about 2 c.p.m. by the use of elaborate shielding, anticoincidence counters, and appropriate circuitry.

The screen-wall counter is placed inside a 1-inch shield of mercury around which is a ring of anticoincidence counters. The entire assembly is inside a 12-ton iron shield, 8 inches thick. The iron removes most of the natural gammas and soft cosmic ray components and reduces the background to about 120 c.p.m. in our laboratory. The mesons that pass through the iron shield trigger a tube of the anticoincidence ring at the same time that they activate the sample Geiger tube in the center. The circuitry is arranged to cancel such a pulse in the sample Geiger tube. This further reduces the background to about 5 c.p.m. About half of this residual count is from the 12-ton iron shield. It turns out that ½ inch of mercury placed inside of the anticoincidence ring absorbs 85 per cent of these gammas and reduces the background to about 2 c.p.m. This situation makes it possible to date materials as old as 30,000 years.

TABLE 1

ARCHEOLOGICAL SAMPLES

| *Sample no.* | *Description* | *Age (years before present)* |
|---|---|---|
| *L-113 | Mayan lintel with carved date | 1,470 ± 120 |
| C-576 | Isaiah manuscript | 1,920 ± 200 |
| C-602 | Stonehenge, England, late Neolithic | 3,800 ± 275 |
| L-134 | Tunisia, early Neolithic | 8,400 ± 400 |
| C-524 | Belt Cave, Iran, Mesolithic | 10,560 ± 1,200 |
| C-579 | France, upper Paleolithic | 13,000 ± 560 |
| C-406 | Lascaux Cave | 15,500 ± 900 |
| C-428 | Oregon sandals | 9,050 ± 350 |
| L-129 | Stomach contents of extinct Moa, New Zealand | 1,800 ± 150 |
| L-127 | Superbison flesh and hair, Alaska | Older than 28,000 |
| L-104A | Signal Butte I horizon, top | 2,950 ± 200 |
| L-104B | Signal Butte I horizon, bottom | 3,440 ± 120 |

*L = Lamont Geological Observatory, Columbia University
C = Institute for Nuclear Studies, University of Chicago

Many specimens of archeological interest have been submitted for carbon 14 dating. TABLE 1 contains a few of these dates, selected to show the kinds of problems to which the method has been applied.

A recent discovery important to Biblical and Semitic scholars was a manuscript scroll of the Old Testament book of Isaiah. Debate ensued as to whether it was written a century or two B.C., in the second century A.D., or whether it was a medieval forgery. The carbon 14 date proved the third view to be impossible, but there was inadequate precision to decide between the other alternatives.

Specimens from England, Tunisia, Iran, and France indicate the time factor for the prehistorical cultures. The Lascaux Cave, site of the famous cave paintings of the extinct woolly mammoths, is the oldest date on a human site so far tested. The woven sandals from Oregon and several other dates from Western caves suggest that man has been in North America at least 10,000 years.

Some selected dates of geological interest are shown in TABLE 2. One of the most important geological problems is the time of retreat of the last continental ice sheet. The first two samples of extinct forest, now overlain by the latest drift, show that the last continental glacier was still in Wisconsin 11,000 years ago. Many additional samples are making it possible to understand the absolute time of the advance and retreat of the ice during the last

part of the ice age. The Mississippi delta and Bermuda samples show the world-wide change in sea level accompanying the last glacial period. The weathered surface at 273 feet corresponds to the maximum sea level lowering. Then, as the ice melted, there is a complete record of sea level rise as a function of time. It was about 80 feet lower than now 11,000 years ago, 70 feet at 9,000 years, 50 feet at 7,000, and 25 feet at 3,000.

A perennial problem of geochemistry and geology has been the origin of petroleum. Most theories included a long period of time, *e.g.*, 1,000,000 years for the hydrocarbon molecule to be prepared. This was followed by migration and accumulation. Further, it had been frequently stated that Recent marine sediments contained no hydrocarbons. Paul V. Smith, Jr.,[7] of the Esso Laboratories, making use of modern organic techniques in brilliant fashion, began a new search for such hydrocarbons and discovered them in appreciable quantities. Not only did he find enough hydrocarbon to account for known petroleum reserves, but the spectrum of compounds was similar to crude oil. The problem remained as to whether these hydrocarbons had diffused up from oil-bearing horizons below or whether they really form *now*. Although the extremely small quantities of hydrocarbon available required the development of special techniques, it was possible by carbon 14 determinations to demonstrate that the hydrocarbons were geologically Recent, and thus the problem of the origin of oil becomes the problem of accumulation only.

Both of the basic assumptions in the method, namely the constancy of the $C^{14}$ concentration in the carbon dioxide cycle and the constancy of the cosmic flux have now been checked experimentally.

Calibration measurements on historically dated material prove no appreciable change in cosmic ray flux in the last 10,000-15,000 years. Recently, the experimental proof of the constancy of the cosmic ray flux over the past 30,000 years has been given by Kulp and Volchok.[6] This was accomplished by dating samples of a homogeneous core both by the ionium method developed by Urry[8] and the carbon 14 method. The ionium method depends on the fact that ionium ($Th^{230}$) is preferentially adsorbed on deep-sea sediments and decays with a half-life of 83,000 years, until equilibrium with uranium in the sediments is reached. This method is applicable to deep-sea sediments of a constant mineralogical type that have been continuously deposited. The method clearly does not depend on the cosmic ray flux. Six samples from three different cores, ranging from 6,000 to 30,000 years in age, were analyzed for ionium and carbon 14. The ages for each sample by the independ

TABLE 2
GEOLOGICAL SAMPLES

| *Sample no.* | *Description* | *Age (years before present)* |
|---|---|---|
| C-308 | Two Creeks, spruce wood | 10,880 ±740 |
| C-366 | Two Creeks, peat | 11,100 ±600 |
| *L-125I | Mississippi delta, weathered surface, 273' | Older than 30,000 |
| L-125G | Mississippi delta, shell 73' | 9,000 ±200 |
| L-125A | Mississippi delta, wood 25' | 2,900 ±300 |
| L-111A | Bermuda drowned forest, 70'-90' | 11,500 ±700 |
| L-111B | Bermuda peat | 6,900 ±150 |
| L-141A | Florida Everglades peat | 4,900 ±200 |
| L-114A | Southern California, 75' (lowest) terrace | Older than 30,000 |
| L-102A | La Soufriere, charred wood from last eruption | 550 ±150 |
| L-101B | Eagle River, Alaska, peat | 14,300 ±600 |
| L-150C | Rapa Island, Central South Pacific lignite | Older than 30,000 |

*L = Lamont Geological Observatory, Columbia University
C = Institute for Nuclear Studies, University of Chicago

TABLE 3

SEA WATER SAMPLES
DEPTH < 10,000 FEET

| Sample | cpm | Sample | cpm |
|---|---|---|---|
| 183 D | 5.72 | 172 B | 6.11 |
| E | 6.23 | C | 6.28 |
| L | 5.86 | D | 6.05 |
| M | 6.02 | E | 5.98 |
| O | 5.93 | H | 5.94 |
| Q | 5.86 | I | 6.00 |
| S(2) | 5.84 | K | 5.85 |
| T | 5.58 | L | 6.13 |
| | 5.88 ±.13 | M | 5.83 |
| | | N | 5.51 |
| | | P | 5.25 |
| | | S | 5.90 |
| 164 A | 6.07 | | |
| B | 5.92 | | 5.90 ±.20 |
| C | 5.85 | | |
| | 5.95 ±.08 | | |

ent methods agreed within the limits of experimental error. The error was sufficiently small to demonstrate the constancy of cosmic ray flux within 5-10 per cent through the past 30,000 years.

It has been shown by Libby[1] that the biosphere has reasonably complete mixing. About two dozen living trees from all over the world gave the same carbon 14 concentration within about 10 per cent. However, for precision dating, particularly of geologically young samples, the quantitative relationships between the $C^{14}$ in the atmosphere, hydrosphere, and biosphere are important. The Lamont laboratory reported values of 6.32 c.p.m. for air samples in October 1952 and 6.07 and 6.72 c.p.m. for wood and shells respectively in November, 1951. All values of activities are for 8 gm. samples which have been corrected to 100 per cent carbon after analyzing for water and ash percentages. They represent a fixed counter geometry containing a thick source of carbon spread over 425 $cm^2$. Subsequent changes in analytical procedure, counter improvements, and the detection of atmospheric contamination during periods of atomic explosion tests made it necessary to review the early results. In particular, the shell value which was based on two samples is suspected of contamination.

In order to examine further the possible variation in the $C^{14}$ concentration of carbon reservoir, therefore, an extensive survey of the activity of contemporary carbon has been started at Lamont.

In a system at thermodynamic equilibrium, the various compounds will concentrate the heavy species of an isotopic pair in the order of increasing partition function ratios of the compounds. The partition function ratios for $C^{14}$-$C^{12}$ isotopic molecules will be the square of those for $C^{13}$-$C^{12}$ isotopic molecules but, since the isotopic exchange equilibrium constants are close to 1, the enrichment factor for $C^{14}$ should be about twice that for $C^{13}$. $C^{13}$ variations have been measured and can be measured with much greater precision than $C^{14}$ variations. Therefore, it is reasonable to use these to predict $C^{14}$ variations. When this is done, some discrepancies appear between the predicted and measured values.

In discussing the results, it would seem logical to start with the activity of sea water since the sea is the controlling part of the reservoir. TABLE 3 gives the results obtained for water samples at depths of less than 10,000 feet in the Atlantic Ocean. The samples were taken on three separate cruises during the last two years by Doctor

TABLE 4

AIR SAMPLES TAKEN OVER NORTH AMERICA

| Sample | cpm | Location |
|---|---|---|
| 165 G | 5.99 | Wheaton, Ill. |
| H | 5.72 | Rawlins, Wyo. |
| I | 5.64 | Wells, Nev. |
| J | 5.38 | Bend, Oregon |
| K | 5.75 | Blair, Nebraska |
| N | 5.12 | Beartooth, Montana (night) |
| P | 5.75 | Frontier, Colo. |
| Q | 5.29 | Needles, Calif. |
| R | 5.31 | Vallejo, Calif. |
| S | 6.31 | Albuquerque, New Mexico |
| V | 5.85 | Spruce Pine, N. C. |
| Average | 5.64 ±.27 | |

Maurice Ewing[9] and his associates at the Lamont Observatory. Each result is an independent sample. The plus or minus on all samples is the average deviation. Each individual result is, in most cases, better than ± 0.2. However, this is well outside of the statistical error which usually runs about ± 0.1. The non-statistical error is due to contamination, electronic variation, counter history and procedure.

TABLE 4 shows the data for carbon dioxide samples taken from the atmosphere over land at different elevations, times of day, and climatic conditions.

The tree samples listed in TABLE 5 are all from the Lamont Campus. These values compare well with the 6.07 reported in November, 1951. Blau, Deevey and Gross[10] at Yale get 5.84 c.p.m. for five samples with apparently similar geometry while Anderson, Levi, and Tauber[11] at Copenhagen report 5.88 and 5.66 c.p.m., based on four and three samples respectively, taken during two different periods. These differences may be ascribed to differences in counter sensitivity and to variable contamination of the blank (background) side of the sample cylinder on one end of the counter tube wall.

TABLE 6 shows the results obtained on three groups of shell samples. The meats associated with the shells of the 200 series are also reported. These results on the Onotoa and Saipan samples, when compared with the 6.7 reported for shells in November, 1951, had led to the hypothesis of contamination of some shells due to upwelling of old water. While this process undoubtedly occurs, it does not appear to be a significant one in the Onotoa-Saipan area. The Long Island clam and oyster samples gave very consistent results and the difference in specific activity between the shell and the meat for each sample is probably real. The errors listed are again the average deviations and may be somewhat conservative.

A summary of the results is given in

TABLE 5

WOOD SAMPLES
(from Lamont Campus)

| *Sample* | *runs* | *cpm* |
|---|---|---|
| 184 A Birch | 3 | 6.14 |
| B Elm | 3 | 6.15 |
| C Cedar | 2 | 6.05 |
| D Maple | 2 | 6.08 |
| E Oak | 2 | 6.07 |
| F Chinese Maple | 3 | 5.98 |
| G Dogwood | 1 | 6.24 |
| H Cherry | 4 | 6.02 |
| I Tulip | 3 | 6.23 |
| J Rhododendron | 3 | 6.12 |
| K Hemlock | 2 | 6.13 |
| L Ghinko | 5 | 6.21 |
| **Average** | | 6.12 ±.06 |

TABLE 6

SHELL AND ASSOCIATED MEAT SAMPLES FROM LONG ISLAND SOUND

| *Shell sample* | *cpm* | |
|---|---|---|
| | | clam |
| 200 B (5) | 6.04 | " |
| C (4) | 6.10 | oyster |
| D (3) | 6.12 | " |
| | 6.08 ±.03 | |
| | from Onotoa | |
| 151 A (2) | 6.35 | |
| B (2) | 6.57 | |
| C | 6.26 | |
| D | 6.26 | |
| E | 6.13 | |
| F | 6.54 | |
| G | 6.42 | |
| | 6.36 ±.13 | |
| | from Saipan | |
| 152 B | 6.26 | |
| C | 6.10 | |
| D | 6.15 | |
| E | 6.00 | |
| F | 6.06 | |
| G | 6.20 | |
| H | 6.56 | |
| | 6.19 ±.13 | |
| *Meat sample* | | |
| 200 E (5) | 5.77 | |
| F (6) | 5.84 | |
| G (3) | 5.67 | |
| H (3) | 5.67 | |
| | 5.74 ±.07 | |

TABLE 7. Using Craig's[12] $C^{13}/C^{12}$ data we should expect that, with the help of efficient atmospheric mixing, the large reservoir of inorganic carbon in the ocean would keep the relatively small atmospheric reservoir about 1½ per cent lower in $C^{14}$ than the surface sea water. Air, in turn, should be about 3½ per cent higher than modern wood. On the marine side of the cycle, plants and meat would be predicted to be about 2½ per cent lower than the surface sea water while the shells would be the same or very slightly lower than the surface sea water. Shells would thus be expected to be from 5 to 5½ per cent higher than modern wood on the basis of $C^{13}/C^{12}$ data.

TABLE 7

SUMMARY OF MODERN VALUES

| *Samples* | *cpm* |
|---|---|
| Sea Water | 5.90 ±.16 |
| Air over land | 5.64 ±.27 |
| Meat associated with shells | 5.74 ±.07 |
| Shells | 6.24 ±.15 |
| Wood | 6.12 ±.06 |

TABLE 7 would seem to show that very few of the above predictions are borne out by present experimental results. Instead of a 5-5½ per cent difference, shells and wood have the same $C^{14}$ concentration. In fact, if only the latest shell values are averaged the result is 6.08 c.p.m. Therefore, surface sea water, shells, and modern wood have the same activity within the experimental error. This result has also been observed at the Yale Laboratory on a few samples.[10] It has been suggested that the ocean carbonate is constantly mixed with "old" carbonate, either through exchange with old water masses from the depths, or from old carbonate sediments on the ocean floor. The meat associated with the shells is lower than the shells, as was expected. If the surface sea water samples are representative of the surface water as a whole and the experimental values are correct, then any reasonable rate of exchange of $CO_2$ between the sea and the air will result in a $C^{14}$ concentration in the air which is lower than the Lamont modern wood value. This suggests that the wood value may be the anomalous one in spite of the good reproducibility. The wood samples were all made up of twigs representing 1-3 years growth of trees on the Lamont Campus. Periodic atmospheric contamination due to local fallout particularly during the spring seasons of the last few years might allow $C^{14}$ atoms to be built into the twigs, thus raising our wood value without any appreciable change in the average air value. It is possible that the air results are low due to the addition of dead $CO_2$ from the oxidation of oil in the air compressor used in the sampling. This possibility is being checked experimentally.

In order to work out this intensely interesting fine structure of $C^{14}$ variation by counting elemental carbon, it is apparent that new precautions and controls of a different order of magnitude than those now in use would have to be employed so that increased precision could be obtained. It is likely, therefore, that an equivalent effort put into the development of other methods would yield greater dividends. Dr. Hans Suess[13] of the U. S. Geological Survey has already proved that the proportional gas counting of acetylene can produce higher precision than the solid carbon Geiger inting method. Liquid scintillation countof benzene is a second possibility. Both methods are under development at the Lamont Observatory. As soon as these techniques are improved to the point of routine operation, the details of the natural $C^{14}$ distribution should be resolved.

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## *SECTION OF PHYSICS AND CHEMISTRY*

# THE METAL CHELATE COMPOUNDS OF PROTEINS*

*By* ROBERT C. WARNER**

The amino acid side chains of all proteins contain a variety of chemical groups that may act as electron pair donors in the formation of coordinate bonds with metal ions. Since the donor properties of these groups should not be significantly modified in the protein, they may be presumed to be the locus of binding of metal ions to proteins. The side chain groups that can be thus involved are the carboxylate, phenolate, amino, imidazole, guanidyl, sulfhydryl and possibly the primary hydroxyl and the amide group of the peptide bond. While a number of metal ions may participate, those most frequently occurring in protein chelates are the ions of Mg, Mn, Fe, Co, Ni, Cu, and Zn. Additional donors of other types may be found within the prosthetic groups of some proteins. Most of the well-known metalloproteins, such as hemoglobin, involve donors from this source. This discussion, however, will be limited to the compounds which are formed, utilizing the side chain donor groups listed above.

Two types of metal protein coordination compounds can be distinguished experimentally. The first of these is illustrated in recent studies of the binding of copper, zinc, and other metal ions by serum albumin.[7,11,12,13,23] It is apparent that the metal ions are bound in what may be termed a nonspecific manner. That is, most or all of the carboxyl, imidazole, and amino groups participate in the binding depending on the pH of the solution. The extent of the binding increases as the free metal ion concentration increases, without approaching any well defined limiting value within the experimental range of this variable. A comparison of the stability constants for the association of the metal ion with imidazole and with the histidine side chain of serum albumin has been made for zinc, cadmium, and copper.[6,7,23,24] Essentially the same values for the first association constant of the metal ion with imidazole were obtained as for the intrinsic association constant for binding by the protein. The actual sequential association constants of the metal ions with the protein is, of course, subject to modification by statistical and electrostatic effects. A similar approximate comparison of the binding of cupric ion by serum albumin at pH 4.5 indicated that the carboxyl groups are the chief donors and that the stability constant is comparable to that for cupric ion in acetate solution.[12] It is indicated by these comparisons, that the intrinsic donor properties of the groups are subject to only slight modification when they are part of the protein. It may also be concluded that the coordination is largely that of one donor to one metal ion. This was pointed out by Gurd and Goodman in the case of the coordination of zinc with the imidazole group of serum albumin.[7] They also produced more direct evidence of this one to one relationship by an analysis of the displacement of protons by the zinc ion.

In sharp contrast to this type of binding is the coordination of ferric, cupric, or zinc ion by conalbumin.[25,26] Two metal ions are bound per mole of protein, with the formation of a colored species having an absorption maximum of 470 m$\mu$ for the ferric and 440 m$\mu$ for the cupric compound. The limiting stoichiometric binding is approached very sharply at extremely low concentrations of free metal ion. One bicarbonate ion per metal ion is also bound. The intrinsic

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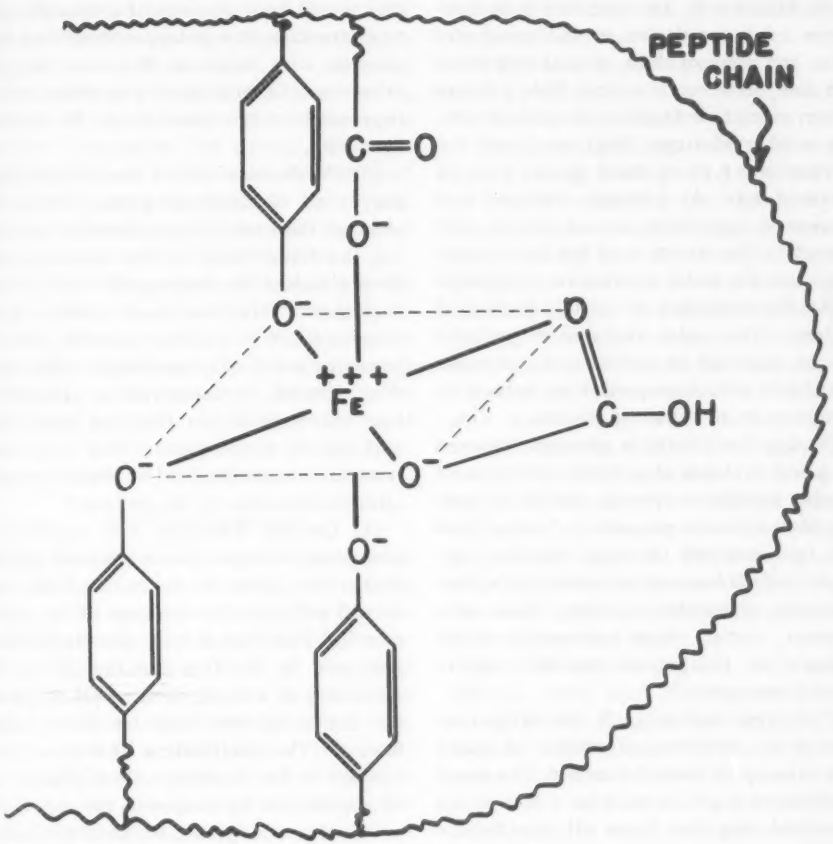


FIGURE 1. Diagrammatic representation of the ferric ion, bicarbonate chelate of conalbumin.

stability constant for the association of a ferric ion is about $10^{29}$. In FIGURE 1 is shown a structure for the ferric chelate based on evidence previously presented.[26] Three of the donors are indicated to be phenolate side chains of tyrosine. Protons are displaced from these donors when the chelate is formed at a neutral pH. A fourth side chain donor has been assumed to be a carboxylate group.

These two types of metal protein compounds correspond essentially to the distinction commonly made between metal complexes and chelates.[16] In the former, one or more monodentate donors are coordinated by a single metal ion, while in the latter the donor is bi- or multidentate and, as a result of chelation, one or more rings are formed. The one to one relation of nonspecific binding conforms to this definition

of a complex, in contrast to the chelate nature of the type of configuration illustrated in FIGURE 1. As compared with complexes, chelates derive an additional stability and many of their special properties from the formation of a ring. This process is very sensitive to steric considerations. The number of rings, their size, and the position and type of donor groups play an important role. As a result, chelates may possess a specificity or selectivity with respect to the structure of the donor molecule or to the metal ion that is comparable to the discrimination evident in biological systems. The metal chelates of proteins may be expected to exhibit some of these specific or unique properties or, indeed, to have them to an enhanced degree.

The basic similarity in structure between the metal chelates of proteins and those of simpler organic compounds results in certain similarities in properties. Among these may be mentioned the high stability constants and the frequent occurrence of a characteristic absorption of light. There are, however, certain other respects in which features of the protein chelates require special comment:

(1) Protein chelates will form rings containing an undetermined number of atoms from nine up to several hundred. The usual requirement that a chelate be a five or six membered ring thus loses all significance and ring size ceases to be of importance in determining stability.

(2) In the protein chelates, the factors determining stability must be related to some other aspect of the native protein structure. This structure is generally assumed to be characterized by a rigidity which fixes the relative position of various parts of the peptide chain and of the attached side chains. This, together with a particular sequence of amino acids in the peptide chain, is here assumed to provide a group of two or more donors in positions such that they can coordinate a single metal ion. This group will constitute a binding site. The existence and nature of such a site would be a property of a specific protein structure. It may be presumed that this specific site arises in the same way as other specific biological properties and is impressed on the structure at the time of synthesis.

(3) The denaturation of the protein which leaves all of the donor groups intact, but changes their relative positions by destroying the fixed fabric of the native protein should disrupt the binding site and prevent chelation. This has been confirmed for conalbumin.[27] It is also probably true of numerous metal enzyme systems which lose their activity on denaturation, although it has not been shown that the metal dissociates in these cases. This is in contrast to nonspecific binding which persists after denaturation of the protein.*

(4) Chelate formation will introduce a new cross linkage between adjacent peptide chains or parts of the same chain and should stabilize the structure of the native protein. That this is true of conalbumin is indicated by the fact that the rate of denaturation at a fixed, alkaline pH is greater for the metal-free than for ferric conalbumin.[26] The contribution of such a cross linkage to the stability of the protein can be appreciated by comparing the one or two covalent or strong ionic bonds of the chelate with the weaker stabilizing effects of hydrogen bonds and electrostatic interaction that are commonly considered to be significant. Some modification or stabilization of the structure of conalbumin may be inferred from the interaction between the two metal binding sites in a single molecule. The interaction is such that the second metal ion is more readily associated than the first. This has been interpreted as a cross bonding of parts of the peptide chain by the first

*This was shown to hold qualitatively in experiments with bovine serum albumin in which cupric ion binding was followed spectrophotometrically. Quantitative changes in the binding were not investigated.[27]

ion bound, in such a way that the donors of the second site are more favorably arranged in a geometric sense for chelation of the second ion.[26] In some proteins, the stabilizing effect may be such that it is essential in maintaining the native structure, that is, it may be impossible to remove the metal without denaturing the protein. While no cases have been conclusively demonstrated, a number of enzymes, such as carboxypeptidase,[30] are known from which the metal has not been successfully removed.

(5) All of the coordination places of the metal are not necessarily occupied by donors from the protein. The bicarbonate ion in the conalbumin chelate as shown in FIGURE 1 is an example.[26] Chelation of an additional molecule in this manner is of primary importance in the enzymatic function of protein metal chelates.

### *Stability Constants*

The distinction between metal complexes and chelates of proteins is most clearly seen in the respective values for the stability constants. The logarithms of the constants for the association of one donor molecule with the cupric ion for the following donors are approximately: carboxylate, 2.1;[17] imidazole, 4.6;[6] amino, 4;[1] phenolate, 4.* These values were determined or estimated for simple donor molecules, but will be considered to hold for the similar side chain donor groups. The logarithmic stability constant for the cupric conalbumin chelate is about 16. This chelate is formed at the same binding site as the ferric chelate, but appears to involve only two of the phenolate donors.[26] The log constant is nearly double the sum of the constants of the donors contributing to the chelate. This extra stability is common in chelates and depends largely on steric factors, as shown by the influence of size and number of rings in several homologous series of chelates.[16]

*Estimated to be the same as an amino group. See reference 19, page 169.

In a protein, this may depend on the geometric arrangement of the donors which constitute the binding site. The stability would then vary with the degree to which a given set of donors formed an unstrained configuration with the metal ion. The possibility of forming less stable chelates due to strained configurations may give rise to cases of metal binding with properties intermediate between the two extremes considered above. A small degree of such chelation arising from the possible favorable position of two donors, even in a random distribution, may contribute to nonspecific binding. The large increase in the stability constant for the chelate, as compared with the complex, is responsible for the observable stoichiometry of chelation, as contrasted with the difficulty of approaching saturation of the available donors by formation of one to one complexes. The coordination of mercuric ion by a sulfhydryl group is an exception. The stability of the complex, in this case, is sufficient to bind two serum albumin molecules together with the formation of a dimer.[8]

Since the protein chelates, such as conalbumin, have many donor groups not involved in the specific binding sites, nonspecific binding may be expected to be superimposed on the chelation and to compete weakly with it for the free metal ion. This situation was demonstrated for the zinc chelate of conalbumin by equilibrium dialysis experiments.[26] The specific linkage was almost saturated before any nonspecific binding could be detected. The extent of the competition will depend on the same factors which determine protein metal complex formation in any other case: the stability constants of the various donor groups as estimated above, the number of groups available, the pH of the solution, and the net charge on the protein. The pH is of particular importance because each of the donors is the basic form of conjugate acid-base system. If the donor is in the

acid form at the pH of the experiment, competition with a proton for the donor will modify the binding. For example, employing the constants given above and assuming that serum albumin contains 16 imidazole and 93 carboxyl groups, it can be estimated that, at pH 7, complexing with imidazole will be dominant and that less than one copper will be bound as a carboxyl complex when half of the imidazoles are combined. On the other hand, at pH 4, imidazole complexes should account for less than 5 per cent of the binding. Higher pH values would have to be attained before amino or phenolate groups participated.

### *Biological Role of Metal Chelates of Protein*

Examples of metal protein chelates may be drawn from compounds serving a variety of biological functions. Very little is known of the structure of these protein compounds or even of the nature of their donor groups. They may be classified as chelates, as previously defined, on the basis of a few of the properties associated with them. Stoichiometry, or at least limited binding, has been demonstrated in a number of cases. The binding is frequently accompanied by a characteristic absorption of either visual or ultraviolet light or is associated with some other specific property such as the binding of oxygen or an enzymatic activity. Some examples, classified according to function, follow. Chelates involving prosthetic groups have not been included.

(1) Metal transport. The $\beta$ metal binding globulin of serum appears to be very similar to conalbumin in its binding properties and, therefore, presumably in the nature of its metal binding sites.[14, 22] The function of conalbumin has not been determined, although it may be a metal transport or storage agent.

(2) Oxygen carriers. The familiar oxygen transport pigment, hemoglobin, is an iron chelate formed by donors from the prosthetic group and is in a separate class from the chelates considered here. Two others, however, bind fixed quantities of metal ions which are stoichiometrically related to the oxygen carriage. No prosthetic groups appear to be involved. These are the copper hemocyanins of various molluscs and arthropods[2] and the iron hemerythrin found in the sipunculid worms.[5, 18]

(3) Metal enzymes. Many enzymes are known in which the binding, or at least the presence of a metal ion, is essential for the catalytic activity. In most cases, some of the features of chelates are evident.

(4) Speculatively, it may be suggested that the mechanisms for distinguishing the bulk cations in physiological systems are based on protein chelation reactions. Chelation provides, by analogy, a degree of selectivity or specificity not found in other reactions of metal ions. Proteins provide the possibility of arranging a limited number of donors in essentially unlimited ways. This may permit the formation of chelating sites which will make possible a discrimination based on differences in the relatively weak chelating ability of the ions. These differences are in the direction of a greater chelating tendency for sodium ion than for potassium, and for magnesium than for calcium.

### *Metal Enzymes*

The metal activated enzymes are of particular interest in the opportunities that they offer for analysis of the mechanism of enzyme action in general. These advantages arise from the analogies that are apparent with the catalytic activities of metals by chelation mechanisms in non-enzymatic cases. The relation of chelate formation to activity, in the case of proteolytic enzymes, has been described by Smith[19] and has recently been discussed, in relation to these and other enzymes, by Martell and Calvin.[16] A few points regarding this relationship may be emphasized. The metal ion may be

presumed to be chelated with the substrate as well as with the protein and thus to form a bond between them in the catalytically active compound. The reasons for assuming the protein metal combination to be chelate in nature have already been discussed. Chelation with the substrate would appear to be necessary to explain the specificity of the enzyme. In the case of carboxypeptidase, Smith and Hanson[20] have obtained direct evidence that two donor groups can be accommodated by the magnesium ion bound to the protein. It may also be noted that two of the common activating metal ions, magnesium and manganese, form such weak coordinate bonds that, in general, their complexes are not stable in solution although their chelates may be.

Three aspects of the sequence of reactions involved in metal enzyme catalysis may be distinguished. They are not necessarily separate steps and may be differently involved in different reactions. Any one may be a rate-limiting step.

(1) Formation of the enzyme-metal-substrate compound. If this is of the type of double chelate suggested above, it may be profitable to distinguish those cases in which the metal is so tightly bound to the protein that no significant dissociation takes place from those in which the metal ion is readily dissociated. The formation of the catalytically active compound in the first case requires only the chelation of the substrate. If the metal ion is readily dissociable, chelation of the ion separately, either with the protein or with the substrate, may precede the formation of the active compound. It is also possible that no combination takes place with either the protein or the substrate separately. The conalbumin-ferric ion-bicarbonate chelate, although not an enzyme, may be an example of this possibility, if the characteristic color of the chelate may be taken as an index of metal binding in the absence of bicarbonate. The process, in general, will certainly be modified by forces operating through other groups than those coordinated with the metal. Smith has emphasized the role of van der Waals' forces in this connection.[19]

(2) Electron redistribution. Catalysis by chelate formation can be based on electron rearrangements within the protein-metal-substrate compound by types of resonance and inductive displacement of electrons that are not possible in the substrate itself. These may lead to spontaneous rearrangements of atoms or may make the compound more sensitive to acid or base catalysis. In two cases in which some understanding of this process has been achieved, there is significant catalysis by a metal ion alone and a greatly increased rate when the enzyme and the same or another metal ion are employed. The studies of the decarboxylation of $\beta$ keto acids by Kornberg, Ochoa, and Mehler[15] and by Steinberger and Westheimer[21] have resulted in specific suggestions as to the role of chelation in the process. The mechanism of the catalytic oxidation of ascorbic acid by copper as elucidated by Weissberger,[18, 19] appears to be closely related to the action of ascorbic acid oxidase which has been studied by Dawson and his co-workers.[3, 4, 9, 10] The reason for the added rate effect of the enzyme in these examples is not clear. The minimum requirement for understanding the role of the protein is certainly a determination of the nature of the donor groups.

(3) Dissociation of the products. Under the conditions of concentration prevailing when the reaction is proceeding in a net amount in one direction, the products must have less affinity than the substrate for the protein-metal. This condition may be met in a variety of ways. In a hydrolytic process, the hydrolysis may correspond to the breaking of one chelate ring so that the decreased stability of the resulting complexes, as compared with that of the chelate, may favor dissociation. In ascorbic acid

oxidase, the copper is reduced to the cuprous form and permits dissociation because of the decreased stability of the cuprous as compared with the cupric chelate.[3]

*Summary*

Two classes of metal protein compounds may be distinguished without considering the cases in which a prosthetic group is involved: (1) complexes in which a metal ion is coordinated with a single donor group supplied by an amino acid side chain; (2) chelates in which the metal ion is coordinated with two or more such donors. Some chemical and biological properties of the latter class have been discussed.

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## *SECTION OF BIOLOGY*

# BIOLOGICAL TRANSMISSION OF PLANT VIRUSES BY ANIMAL VECTORS*

*By* KARL MARAMOROSCH**

Plants, like animals, are subject to infectious diseases caused by fungi, bacteria, and viruses. Virus diseases of plants are, for the most part, arthropod-borne. The word *vector* is commonly used to indicate the invertebrate transmitters necessary for the successful passage of certain disease agents from the infected to the noninfected host. The term derives from the Latin *vehere*, to carry. The arthropod vectors are quite often, however, not merely carriers; they may serve as alternate hosts or constitute important reservoirs of certain disease agents.

Most vectors of plant viruses are found among the Aphididae (aphids), Cicadellidae (leafhoppers) and Aleyrodidae (white flies). Only a few viruses are transmitted by insects of other groups, like Coccidae (mealybugs) and Thysanoptera (thrips). The transmission of a plant virus by a member of the Acarina (mites) was recently reported.[39]

In order to ascertain that an arthropod is a vector of a given plant virus in nature, the infection must be reproducible experimentally by the use of the arthropod, under controlled conditions, through feeding on susceptible plants and with adequate uninfected checks. In practice, this test alone is usually sufficient for the establishment of a virus-vector relationship. Animal virologists usually require additional criteria, such as a close association of the arthropod with the infected host, regular visits to the healthy animal under conditions suitable for the exchange of the virus, and the presence of the virus in the arthropod host.[35] These criteria are required because almost all animal viruses can be transmitted mechanically to their warm-blooded hosts. Many plant viruses, however, cannot be transmitted mechanically to plants and thus some of the mentioned criteria cannot be applied. In fact, they would often be misleading in the study of plant virus transmission. An occasional, rare visit of an insect not ordinarily associated with a given plant may be sufficient to cause infection and the disease signs may appear years later when no insects of the proper species are present in the area. In cases where no close, easily observed association between vector and plant occurs, the discovery of vectors becomes a very tedious and difficult task. This is clearly manifested in a number of virus diseases of stone fruits.

Arthropods seem to constitute a reservoir of plant-pathogenic viruses and plants may often serve as only incidental hosts for the many viruses harbored by insects.[31, 33] Similarly, man and many other species of vertebrates serve as incidental hosts for the viruses of yellow fever, louping-ill, and Colorado tick fever.[35, 38] The plant and the warm-blooded animal hosts may be regarded, in these cases, as only temporary repositories and the disseminators of viruses to the main, mobile reservoirs—the arthropod vectors.

In the transmission of plant viruses, two major types of virus-host relationship are usually recognized. Vectors of one type may acquire a virus in short feeding periods and transmit it almost immediately but in every known case such vectors soon lose the virus. Vectors of the second type may also acquire virus by feeding for short periods on infected plants, although generally longer acquisition feeding is required. In contrast to the first type, the vectors are unable to transmit virus to healthy plants immediately. An incubation period of con-

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siderable length occurs between the acquisition of virus and its transmission to a susceptible host. After an incubation period of many hours, days, or even weeks, the vectors of this type become infective. The plant virus is retained by the arthropod vector for a considerable length of time, often for the remainder of the insect's life, without need of replenishment from infected plants. The virus-vector relationship, in this case, represents a highly specialized adaptation of the virus to the arthropod host. This obligatory relationship between the vector and the transmitted virus is indicated by a high degree of specificity; in the majority of cases one or a few closely related species are found to transmit a given virus. This relationship is often called *biological* and the transmission known as *biological transmission.*

In several biologically transmitted viruses it has been shown experimentally that the viruses multiply in the arthropod vectors. Recently Black[4] and Maramorosch[30] have critically reviewed the evidence on multiplication of certain plant viruses in their insect vectors. Four viruses were found to pass transovarially to the progeny of infected females. Such hereditary transmission may pass virus either to a high or a low percentage of the offspring.[6, 9, 13] Recognition of the fact that a virus is capable of multiplication both in plant and arthropod hosts and that its transmission depends directly on a specific insect is of basic importance. The ability of the parasite to adapt itself to such diverse conditions seems to support the concept of the living nature of viruses.

Aphids transmit the largest number of plant viruses but only a few viruses spread by aphids are transmitted biologically. The virus of potato leafroll is one of the representatives of this small group. It is retained by its vector *Myzus persicae* and it undergoes an incubation period, but as yet no experimental evidence has been reported in favor of its multiplication in aphids. The long incubation period and retention of strawberry virus 3,[37] and of a few other viruses, also indicate that they are probably biologically transmitted by their aphid vectors.

The cicadellid leafhoppers constitute the largest group of vectors of biologically transmitted viruses. Almost all leafhopper-borne plant viruses undergo an incubation period in their insect vectors. The length of this intrinsic incubation period depends on the nature of the virus, the environment of the vector, and the nature of the vector. In the case of biologically transmitted viruses an attempt is usually made to establish the shortest, or minimum, incubation period. In order to ascertain this period large numbers of insects have to be tested under optimal conditions. Whenever incubation periods for individual insects were recorded, differences were observed in the lengths of these periods; it remains to be seen whether such differences in individual performance are genetically inherited.

In insects inoculated mechanically, the length of incubation period depends on the virus concentration[25, 26] or volume.[24] Individual variation, however, was also observed in insects injected with as nearly equal amounts of virus inoculum as was technically possible.[24] The minimum incubation period of a virus in two species of insects may be of the same or of different length. No difference was found, for example, in the incubation period of wound-tumor virus in *Agalliopsis novella* and *Agallia constricta*,[25] whereas a significant difference was observed in the case of comstunt virus incubation in *Dalbulus maidis* and *Dalbulus elimatus* (Niederhauser, personal communication).

In 1926 Kunkel suggested, for the first time, that the incubation period and persistence of the aster-yellows virus in the aster leafhopper were due to the reproduction of the virus in its vector.[18] To date,

TABLE 1
MULTIPLICATION OF PLANT VIRUSES IN LEAFHOPPER VECTORS

| *Virus (common name)* | *Method of demonstrating viral multiplication* | *Author* | *Year* |
|---|---|---|---|
| Rice-stunt | Transovarial passage (7 generations) | Fukushi[16] | 1940 |
| Aster-yellows | Heat-induced incubation period | Kunkel[19, 21] | 1937, 1941 |
| " | Titration of virus, acquired by feeding, during incubation | Black[3] | 1941 |
| " | Correlation of incubation period in plant and insect | Kunkel[22] | 1948 |
| " | Correlation of incubation in plant and insect at various temperatures | Maramorosch | unpublished |
| " | Effect of concentration on length of incubation | Maramorosch[26] | 1950 |
| " | Titration of virus acquired by feeding as well as by injection | Maramorosch[33] | 1953 |
| " | Serial passage (10 transfers) | Maramorosch[27, 28] | 1952, 1952 |
| " | Effect of volume on incubation | Maramorosch[34] | 1953 |
| " | Arrested incubation period at 0° C. | Maramorosch[30] | 1953 |
| Club-leaf | Transovarial passage (21 generations) | Black[6] | 1950 |
| Wound-tumor | Arrested incubation period at 4° C. | Maramorosch[24] | 1949 |
| " | Effect of dosage | Maramorosch[25] | 1950 |
| " | Correlation of incubation in plants and insects at various temperatures | Maramorosch[25] | 1950 |
| " | Serial passage (7 transfers) | Black and Brakke[7] | 1952 |
| Corn-stunt | Correlation of incubation in plant and insect | Kunkel[22] | 1948 |
| " | Correlation of incubation at various temperatures | Maramorosch | unpublished |
| " | Serial passage (3 transfers) | Maramorosch[29] | 1952 |

multiplication of this virus in the aster leafhopper *Macrosteles fascifrons*, demonstrated in a variety of ways, is the best known example of a versatile virus multiplying in a plant and animal host. In addition, four other leafhopper-borne viruses were shown to multiply in their respective vectors. The evidence of plant virus multiplication in leafhopper vectors is summarized in TABLE 1.

Only one virus, that of spotted wilt, has been demonstrated beyond doubt to be transmitted by thrips.[1] The incubation period of this virus is of considerable length, at least five days. The virus persists in the vector for life. The transmission is specific, as far as could be ascertained, as out of many species of thrips only three were found as transmitters. The possibility of multiplication of tomato spotted-wilt virus in its vector has never been tested experimentally.

In tropical and subtropical areas of the world, white flies (Aleyrodidae) acquire a number of plant viruses which are spread biologically by the adult form, while nymphs remain stationary, attached to plants. Among the white-fly-borne viruses is the causative agent of infectious chlorosis. This disease was long considered a mystery, and geneticists cited it as an example of a plasmagene originating *de novo* due to

grafting of two species.[14] In 1946, Orlando and Silberschmidt[36] found in Brazil the vector *Bemisia tabaci*, and described the biological relationship of the virus to this white fly. Another virus, causing Euphorbia mosaic in Brazil,[13] and one causing Bhendi mosaic in India[43] are also transmitted by species of white flies. These are only a few examples of white-fly transmitted viruses which are characterized by an intrinsic incubation period in the vector and seem to be retained in the arthropod for considerable time.

Mites (Acarina) were known as vectors of animal viruses and of rickettsiae for many years, but none were reported as vectors of plant viruses. Recently, however, Slykhuis[39, 40] presented evidence that a mite, *Aceria tulipae*, transmits the virus of wheat-streak mosaic. In view of this finding, it will be interesting to investigate certain virus-like diseases of plants earlier reported as due to feeding or association with mites. From published accounts, it seems that wheat-streak mosaic virus is transmitted biologically by its mite vector.

What happens to a biologically transmitted virus after it is acquired by an arthropod vector? While a vector is feeding on an infected plant, virus is sucked up through the mouthparts and ingested; it is not just carried on the outside but enters the animal host. It seems probable that virus taken into the gut passes through the gut wall into the blood, from which it can reach the salivary glands and the saliva and thus get into a position from which it can be injected back into plants by the feeding vector. During the long incubation period observed in biologically transmitted viruses, the small initial amount of acquired virus not only moves through the insect body but also multiplies to an infective concentration. When the virus is found in the blood it causes viremia, a systemic infection, but no disease of the vector. So far, it has not been established in what organs of the vector the multiplication takes place, nor how viruses manage to pass through the gut wall of a vector.

Specificity was mentioned as a characteristic feature of biological transmission. There are different degrees of vector specificity. The adaptive capacity of plant viruses, as remarkable as it seems to be, undoubtedly has its limits; plant viruses are, by far, more limited in their arthropod host range than in their plant host range. The problem of leafhopper specificity has been reviewed by Black.[10] The same author found that two strains of a virus may have two different insect vectors.[4] Recently, Black reported the loss of vector transmissibility by viruses normally insect-transmitted. This loss occurred when viruses were maintained for long periods of time in plants propagated vegetatively.[11] It would be interesting to test the ability of such viruses to adapt themselves again to their former vector species.

It was shown that several plant viruses acquired by nonvector species of arthropods may be retained in nonvectors for considerable lengths of time without, however, being transmitted.[2, 29, 41, 42] Obviously, lack of transmission is not caused by virus inhibitors in nonvectors. Storey found that inactive *Cicadulina mbila* can be transformed into active transmitters by puncturing the insect's gut wall. Mere penetration of the gut wall, however, could not explain vector specificity, as the same puncturing was ineffective in converting other related and unrelated species of insects into active transmitters.[25, 29, 42]

It seems plausible that viruses are unable to multiply in nonvector species and that the specificity of their transmission is a direct result of this limitation. An attempt was recently made to explain the nature of specificity of vectors of biologically transmitted viruses on that basis. Experimental evidence indicated that specificity of transmission of aster-yellows and corn-stunt vi-

ruses depends on the ability of these viruses to multiply adequately in their vectors but not in nonvectors.[29] Corn-stunt virus could be recovered from nonvector species of leafhoppers which fed on diseased corn plants, and similarly aster-yellows virus could be recovered from nonvector species. The viruses were not inactivated by the blood of the nonvectors; nevertheless, they were not transmitted. They also could not be passed in series through nonvectors. A titration of aster-yellows virus obtained from nonvectors and from vectors was made three weeks after acquisition of virus. The virus was recovered from its vector up to a dilution of 1:1000, whereas from nonvector species it could be recovered up to a dilution of 1:100. This seemed to indicate that the virus recovered from the nonvector represented the original amount of virus acquired by feeding without any further increase, or after a very limited multiplication. The lower concentration in nonvectors, resulting from little or no multiplication, seemed to be responsible for the inability of other species of insects to transmit this virus. The retention of the virus in vectors and nonvectors also differed; aster-yellows virus was retained throughout life in the aster leafhopper but slowly disappeared in nonvectors.

The finding that plant viruses multiply in their vectors has a bearing on our ideas about virus multiplication, classification, and origin. These viruses cannot be considered as solely plant viruses; they constitute a close link between plant and animal viruses. The ability to multiply in such diversified hosts as plants and animals strongly suggests that they are living parasitic organisms. The hypothesis of a large molecule precursor responsible for virus multiplication can hardly account for multiplication of the plant-animal viruses. It is inconceivable that such a large molecule precursor would occur in two hosts that are serologically and otherwise so unrelated. The morphology of viruses transmitted by leafhoppers shows that they are complex in nature. Presumably the virus particles are surrounded by a membrane.[5, 12] Their morphology and the complex biological behavior seem to place these viruses in the category of microorganisms. They are not only capable of multiplication but they also mutate and, as was shown by Kunkel with aster-yellows virus,[20] such mutations can be induced by physical means, similar to mutations in other microorganisms. Multiplication is an intrinsic character of a functional organism in which like produces like. Viruses, probably, are unable to sustain independent metabolism and this characteristic may be a result of an extreme form of parasitism.[17, 23] Retrograde evolution in parasites might explain the existence of the highly specialized plant-virus-arthropod relationship of biologically transmitted viruses. The virus does not interfere with the life functions of the animal vector. Should it in some way endanger the life span of the arthropod or interfere with its feeding, then chances to transmit the infective agent would be diminished. Is it proper to apply the term *vector* to arthropods and the term *host* to plants? If we look at the problem from the standpoint of disease in plants, the arthropods play merely the role of carriers. But from the virus aspects and its requirements for survival in nature, arthropods transmitting plant viruses biologically often constitute better hosts or reservoirs than the plants.

The life cycles of viruses, alternating between a plant and an arthropod, could have arisen either by very simple nutritive requirements or by a well organized adaptation of all metabolic activities. Our present knowledge of biologically transmitted plant viruses shows that, with certain exceptions, they have a fairly large host range among plant species but a narrow one among the arthropod vectors. This favors the assumption that their adaptation to the animal host is well organized and, from an evolutionary

point of view, probably also of much longer existence. It therefore seems conceivable that these viruses were originally arthropod viruses and, due to the long association between the host and parasite, ideally balanced in their almost symbiont-like relationship. This explanation could account for the complete tolerance of the otherwise highly virulent plant viruses in respect to the "susceptible" arthropods.

The view of the origin of biologically transmitted viruses in arthropods seems further supported by the finding that several viruses have the capacity of passing through the egg of the vector to the progeny and of being thus maintained indefinitely in animals without the necessity of alternating plant hosts. Others are only occasionally transmitted trans-ovarially, and still others have to rely on a complicated life cycle, alternating between plants and arthropods.

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## *Author's Note*

After this paper was submitted for publication, a new leafhopper-borne virus disease was reported from Australia by N. E. Grylls, 1954, Austr. Jour. Biol. Sci. 7:47-50. The causative agent, transmitted transovarially to the progeny of the vector, constitutes the fifth virus transmitted in this manner.

# GENETIC COMPOSITION IN RELATION TO ISOELECTRIC POINT AND SEROLOGICAL REACTION OF STRAINS IN TOBACCO MOSAIC VIRUS*

*By* W. C. PRICE**

About 20 years ago, Jensen[3,4] demonstrated that tobacco mosaic virus (TMV) mutates, thus giving rise to new strains. Jensen isolated more than 50 strains of TMV and studied each in sufficient detail to learn that the symptoms on susceptible plants resulting from interaction between the virus and the host are characteristic of the particular strain of virus and thus involve some sort of a hereditary mechanism. A few years later, Holmes[4] pointed out that mutation in TMV appeared to involve unit factors comparable to the genetic factors of higher organisms. Study of the differences and similarities among mutant strains of viruses offers one approach to solution of the problem concerning the basic nature of viruses, a problem with which all virologists are concerned one way or another.

## *Statement of the Problem*

In the Plant Virus Laboratory, we have isolated about 35 strains of TMV and studied 14 of these in considerable detail in comparison with the Type, Green Aucuba, Ribgrass, and Rosette strains. In the beginning, we were interested in detecting the presence of genetic factors controlling certain aspects of symptomatology in certain host plants. Holmes[4] had shown that there are factors in TMV for yellowing in Turkish tobacco and for invasiveness in the same host, and Kunkel[9] had reported observations which indicated that factors in TMV mutants for green mottling in Turkish tobacco and for localization in *Nicotiana sylvestris* varied individually.[10] We were, therefore, on the lookout for these and similar factors. The search for these factors and the proof of their existence would require more time than is at my disposal; however, their enumeration and description is essential to understanding the work on serology which I wish to discuss in some detail.

TABLE 1

POSTULATED GENETIC COMPOSITION OF 18 STRAINS OF TMV

(See text for description of symbols)

| *Virus Strain* | *Factors* | *Virus Strain* | *Factors* |
|---|---|---|---|
| Type | ylrBGd | R1Y1 | Y-rBGd |
| Green Aucuba | yLrBGd | Y14 | YlrBGd |
| Ribgrass | yLRBGd | Y14G1 | ylrBGd |
| Rosette | yLRbGd | Y14N1Y1 | YlrBGd |
| 2B1 | ylrBGd | Y20R1 | YLRBGd |
| 5 | yLrBgd | Y20Y1 | YLrBGd |
| 5G1 | ylrBGD | Y21R1 | YLRBGd |
| 7A | yLrBGd | Y24Y1 | YLrBGd |
| M1 | ylrBGd | Y25 | YlRBGd |

Six characteristics, or factors, which we believe to be possessed by TMV strains are: Y, ability to cause yellowing in Turkish tobacco; L, localization in *Nicotiana sylvestris;* R, production of ring spots in Turkish tobacco; B, ability to infect bean *(Phaseolus vulgaris* L.); G, production of large local lesions in *Nicotiana glutinosa;* and D, production of strap-leaf in Turkish tobacco. The allelomorphs for these factors will be indicated by a corresponding small letter. The list does not include the factor I for invasiveness reported by Holmes.[4] The genetic analysis, in terms of the six factors, of 18 strains of TMV is in TABLE 1. Evidence is available that each of the six factors varies independently of the other five. The first four strains in the left-hand column of the table will be referred to as wild strains and the remainder as laboratory strains, reflecting their source or origin.

*This paper, illustrated with lantern slides, was the second of two papers in a Symposium on Plant Viruses, presented at a meeting of the Section on January 11, 1954. Some of the work on which this paper is based was supported by a research grant from the Division of Research Grants and Fellowships of the National Institutes of Health, U.S. Public Health Service. It represents work carried out in collaboration with graduate students. Those to whom credit is due are Betty R. Steranka, Ernest P. Weaver, Ellen L. Moorhead, Robert B. Gordon, John J. Boltralik, and Bernard J. Ferraro.

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The problem with which we will now be concerned is to see whether these various factors are independent of the amino acid content, isoelectric point, and serological activity of the particular strains possessing them. Because the amino acid content of only a few of the strains is now known,[8] it cannot be stated categorically that all six factors are independent of the amino acid content, but it is readily apparent that the factor Y, for yellowing, or its allele, y, has little to do with amino acid content.

### *Differences in Isoelectric Points*

Oster[12] found that the pH at which purified preparations of TMV reached maximum optical density varied with the individual strain and that strains therefore could be differentiated on this basis. We[3] used Oster's method to determine whether or not some of our mutant strains could be differentiated in this way. Small increments of 0.0015 N HCl were added to 5 ml. portions of purified preparations, and changes in turbidity measured with a Klett-Summerson colorimeter.

It was found that mixtures of strains behaved like single strains except that the curve obtained by plotting optical density as a function of pH of the solution lay between the curves for the single strains and that the pH of maximum optical density therefore also lay between the pH values for the single strains. For this reason, apparent differences between strains are significant only to the extent that the strains are free of mixtures.

Data on 13 strains of TMV are in TABLE 2. The pH of maximum optical density is independent of virus concentration within the limits 0.1 to 0.3 per cent concentration. The wild strains were easily differentiated on this basis, the pH of maximum optical density varying from 3.67 for the Rosette strain to 4.68 for the yellow aucuba strain. The range for the laboratory strains was much narrower, from 3.78 to 3.98. Nevertheless, it was concluded that mutation in TMV can involve small changes in pH of maximum optical density and, by inference, in the isoelectric point of the virus particle.

The isoelectric point of a virus particle is determined by the charge on the particle and this, no doubt, is largely due to the amino acid composition of the particle. The most startling thing about the results in TABLE 2, therefore, is not that mutant strains can differ in isoelectric point, but that a profound change in symptomatology can take place in a virus strain in the absence of a detectable change in amino acid composition. Differences in symptomatology among laboratory strains in many cases is more striking than differences among the wild strains.

If one compares the values for pH of maximum optical density in TABLE 2 with the genetic composition of the strains (TABLE 1) it becomes apparent that isoelectric point is independent of the factors Y, L, R, G, D, and probably B. Thus far, we have not been able to detect a correlation between the isoelectric point of the virus and any combination of these factors.

TABLE 2

PH OF MAXIMUM OPTICAL DENSITY OF STRAINS OF TMV

| *Virus Strain* | *Percentage Concentration of Virus Used in Test* | | | |
|---|---|---|---|---|
| | *0.30* | *0.22* | *0.15* | *0.10* |
| Rosette | 3.67 | | | |
| Y2OR1 | 3.78 | 3.84 | | |
| Y14G1 | 3.82 | | | |
| #5 | 3.82 | | | |
| | 3.84 | | | |
| | 3.87 | | | |
| Y2OY1 | 3.85 | | 3.84 | |
| Y25 | | | 3.88 | |
| Type | 3.86 | 3.88 | 3.91 | |
| | 3.90 | | | |
| Y14N1Y1 | | | | 3.91 |
| 5G1 | | 3.96 | | |
| 7A | 3.98 | 3.94 | | 3.96 |
| M1 | 3.97 | 3.98 | | 4.00 |
| Ribgrass | 4.02 | | 4.04 | |
| | 4.00 | | | |
| Yellow Aucuba | 4.62 | | | |
| | 4.63 | | | |
| | 4.68 | | | |

### *Serological Reactions*

Purified preparations of TMV strains, obtained by alternating cycles of low speed and high speed centrifugation, were used as antigens to immunize rabbits and to react with prepared antiserum. Rabbits were given a series of injections, intraperitoneally or intravenously, and after a suitable interval were exsanguinated. From 7 mg. to 300 mg. of virus was injected but there was no evidence that antiserum titer was increased by injecting more than 7 mg.

Two types of tests were used for differentiating TMV strains, complement fixation and the sheep red blood cell precipitin test.[11, 14] For the complement-fixation tests, sheep red blood cells, complement, and hemolysin were always standardized before each test and appropriate controls were included in each test; the details of the method are published elsewhere.[14] The sheep red blood cell precipitin test was carried out in plastic plates in which 3/4 inch diameter wells with conical bottoms had been drilled.[13] Antigen, to the amount 0.1 ml. in buffered saline was mixed with 0.1 ml. of antiserum, also in buffered saline, and then 0.2 ml. of a 1 per cent solution of fresh sheep red blood cells were added. The plates were read after storage for exactly 3 hours at 4°C. In controls and negative reactions, the cells settled to the bottom of the wells where they appeared as bright red discs. In positive reactions, the antigen-antibody combination apparently held the cells in suspension so that they failed to settle completely in a 3-hour period.

In grid titrations, 2-fold, or less than 2-fold, serial dilutions of a purified preparation were mixed with 2-fold serial dilutions of antiserum in the possible combinations and the indicator system then added. Results of a grid titration using the sheep red blood cell precipitin test are in FIGURE 1. From data such as these, two constants can be defined. The antiserum dilution end

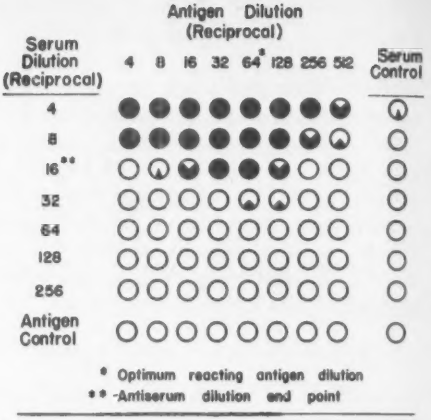


FIGURE 1. Titration of type strain of TMV and the homologous antiserum by the sheep red blood cell precipitin test. Extent of the reaction is indicated by proportion of the circle in black.

point is defined as the highest dilution of antiserum giving a 4-plus reaction with an optimum amount of antigen; in FIGURE 1, this is the 1/16 dilution. The optimum reacting antigen dilution is defined as the highest dilution of antigen giving a 4-plus reaction with the antiserum dilution end point; in FIGURE 1, this is the 1/64 dilution. The optimum reacting antigen dilution contains a weight of virus which is, by definition, the optimum antigenic unit.

These constants are not identical in the two types of tests but they bear a definite relationship to each other. In our hands, the optimum antigenic unit in the sheep red blood cell precipitin test is 1/128 that in the complement fixation test, within the limits of experimental error; and the reciprocal of the antiserum dilution end point in the sheep cell test is 1/8 that in the complement fixation test. These constants also vary with the technique of the observer so that adjustments to a common standard must be made in comparing one observer's results with another's. This adjustment has been made in the discussion to follow.

The optimum antigenic unit is characteristic of a particular virus strain, irrespec-

TABLE 3

RELATIVE ANTISERUM DILUTION END POINTS IN TESTS WITH WILD STRAINS OF TOBACCO MOSAIC VIRUS*

| *Antiserum (Virus Strain)* | *Antigen (Virus Strain)* | | |
|---|---|---|---|
| | *Type* | *Ribgrass* | *Rosette* |
| Type | 100 | 9** | 12.5** |
| Green Aucuba | 100 | 6.2** | 1.5** |
| Ribgrass | 25** | 100 | 3.1** |
| Rosette | 200 | 50 | 100 |

*Figures represent relative values for the reciprocal of the antiserum dilution end point based on a figure of 100 taken arbitrarily for the homologous reaction.
**Significantly different from homologous reaction.

tive of the antiserum used, but varies among different strains. It is thus useful in distinguishing one strain from another. After making adjustments for differences in technique, optimum antigenic units for the 18 strains of TMV varied from 0.9 to 14.8 μg./ml. in complement fixation tests and for nine of these strains the units varied from 0.11 to 0.76 mg./ml. in the sheep cell precipitin test. In tests with the same strain of virus the variation was only 15 per cent. The laboratory strains of TMV varied in optimum antigenic unit somewhat more than the wild strains. It thus seems that these differences represent minor serological differences, useful perhaps in distinguishing one strain from another but not in detecting or studying major changes in the virus particle. The optimum antigenic units for the Type, Green Aucuba, and Ribgrass strains are of the same order of magnitude, yet these are the strains that Knight[6] found to differ in amino acid composition. It seems unlikely, therefore, that genetic factors responsible for amino acid composition are the ones responsible for size of optimum antigenic unit.

In reactions between antiserum and homologous antigen, the antiserum dilution end point is constant for a given antiserum but varies with individual rabbits, the course of immunization, and the kind of antigen used. In our tests, the error in determining the antiserum dilution end point is about 2-fold; consequently only those antiserum dilution end points that differ from others by 4-fold or more can be considered significantly different.

Antiserum dilution end points obtained in cross reactions among the Type, Ribgrass, and Rosette strains of TMV are in TABLE 3. It can be seen from the table that, when tested against the Type strain antiserum, Ribgrass and Rosette antigens gave dilution end points significantly lower than the end point obtained with the homologous virus. When tested against Ribgrass antiserum, the Type and Rosette antigens gave significantly lower dilution end points. On the contrary, when tested against Rosette antiserum, none of the heterologous end points were significantly different from the homologous ones.

An interpretation of these results is that: (1) all three strains have antigenic components in common; (2) the Type strain possesses all the antigenic components carried by the Rosette strain and at least one additional component; and (3) the Type and Ribgrass strains each possess components not carried by the other strain. This interpretation is the same as that arrived at by Chester[3] using the cross-absorption technique.

Differences among strains, reflected by differences in antiserum dilution end points in homologous and heterologous reactions, are major ones. It is possible that they correlate with differences in amino acid composition. If this is so, the laboratory strains differ little, if any, in amino acid composition because they have not been found to differ in antiserum dilution end points in homologous and heterologous reactions.

### *Serological Tests with Iodinated Virus*

We are interested in knowing what structures or groupings on the tobacco mosaic virus particle are responsible for the major serological differences revealed by tests such as those discussed. One possibility is

that a series of mutations involving detectable changes in amino acid composition also involve major serological differences. Nothing in the results reported so far is inconsistent with this hypothesis.

Further tests of the hypothesis can be made by treating purified virus in such manner as to affect or abolish certain side chains on the virus particle and then test for serological differences between treated and untreated virus.

Abolition of the sulfhydryl groups or the cysteine residue can be accomplished by treating the virus with iodine in potassium iodide at pH 7, as has been demonstrated by Anson and Stanley.[1] Further treatment at the same pH leads to oxidation past the disulphide stage. The exact intermediate in this case is not known but Anson and Stanley presented evidence to show that it was not $RSO_3H$. If iodination is carried out at pH 7.7 and 56°C., the tyrosine is converted to diiodotyrosine.

Samples of the Type strain treated in these various ways were tested for serological differences by means of the complement fixation technique. Results obtained are in TABLE 4.

The four different virus antigens were reacted with antiserum to native TMV and antiserum to diiodotyrosine virus. Abolishing the SH groups apparently caused no change in serological activity. Abolishing the S-S linkage resulted in doubling the optimum antigenic unit but caused no change in antiserum dilution end point. On the other hand, a major serological change occurred when tyrosine was converted to diiodotyrosine. In reactions with antiserum to native TMV the antiserum dilution end point was reduced 32-fold.

TABLE 4

OPTIMUM ANTIGENIC UNITS (OAU) AND ANTISERUM DILUTION END POINTS (ADE) OBTAINED IN CROSS REACTIONS BETWEEN NATIVE TOBACCO MOSAIC VIRUS AND IODINATED VIRUS AND THEIR RESPECTIVE ANTISERA

| | *Antiserum* | | | |
|---|---|---|---|---|
| | | | *Diiodo-tyroseine TMV* | |
| *Antigen* | *OAU μg./ml.* | *ADE* | *OAU μg./ml.* | *ADE* |
| Native TMV | 2.8 | 320 | 2.8 | 40 |
| SH Abolished Virus | 2.8 | 320 | 2.8 | 40 |
| S-S Abolished Virus | 5.6 | 160 | 5.6 | 40 |
| Diiodotyrosine Virus | 5.6 | 10 | 5.6 | 20 |

The diiodotyrosine virus was capable of stimulating antibody formation in rabbits although the titer of the antiserum obtained was only about 1/8 that obtained by immunizing with native TMV. This is in contrast to the finding of Kleczkowski[7] who was unable to demonstrate serological activity in diiodotyrosine virus but readily explicable on the basis that Kleczkowski used the precipitin test which is relatively insensitive.

Our antiserum to diiodotyrosine virus reacted with the heterologous antigens with an antiserum dilution end point as high as that obtained in the homologous reaction with the same antiserum. Serological results with native TMV and diiodotyrosine TMV are thus comparable to those obtained with the Type and Rosette strains of TMV; in the latter case there was a significant difference in antiserum dilution end point when antiserum to the Type strain was used but not when antiserum to the Rosette strain was used. It is tempting to conclude that the Rosette strain differs from the Type strain in its tyrosine content but this would be a hazardous conclusion—especially so since it can easily be put to test.

### *Conclusions*

In so far as we have been able to tell, single step mutations which may or may not effect a profound change in symptomatology of tobacco mosaic virus do not effect a major change in antigenicity. It is possible, of course, that we have not dealt with strains in which a single mutation involved

a genetic factor controlling a major antigenic determinant.

The strains of TMV existing in nature are the products of mutation and selection over a relatively long period of time. Opportunity for changes in many genetic factors has thus been available. It is these wild strains in which major serological differences have been demonstrated and it is also these in which major differences in amino acid composition and isoelectric point have been demonstrated. Whether these major differences correlate with single genetic factors or with groups of such factors cannot be ascertained without further experimental work.

It was suggested by Knight[8] that each mutation in a virus particle involves a change in amino acid composition. Failure to detect major differences in isoelectric points and serological reactions among laboratory strains of TMV suggests that mutations effecting no appreciable change in amino acid composition nevertheless effect profound changes in symptomatology. It seems more likely to the writer, therefore, that a mutation in TMV is accompanied by a corresponding alteration in the nucleic acid fraction of the particle and any changes that occur in amino acid composition are incidental.

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## *SECTION OF MATHEMATICS AND ENGINEERING*

# A STOCHASTIC MODEL FOR SOCIAL INTERACTION*

*By* MERRILL M. FLOOD**

### *1. Introduction*

We offer an outline synthesis of some of the results presented in a series of earlier papers, by the present author[5, 6] and others,[2, 3, 4] in the form of a stochastic model for social interaction. Some of the properties of this model, and of its principal components, will also be discussed. The treatment here is necessarily sketchy, but it illustrates the main ideas and serves also as an outline for anyone wishing to trace details by reference to other papers.

Our central object is to construct a mathematical model for the human social interaction process, and to specify an experimental procedure for estimating the parameters that describe the behavioral characteristics of the individual participants. This object was achieved, at least for certain limited types of social behavior, but very little can be said, as yet, concerning the extent to which the theory is valid in other situations.

### *2. The Behavioral Model*

We shall first describe a machine, called SAM, that functions according to the mathematical rules defining our stochastic model for social interaction. In operation, SAM responds to external stimuli in a way that will be likened to the behavior of humans as learning individuals and in social groups.

The external controls and indicators for a SAM are illustrated schematically in FIGURE 1. The six parameter dials and the three probability dials may each be set initially at any value between 0 and 1, inclusive, provided only: (a) That the sum of the settings of the three probability dials is unity; and (b) That the sum of the dial settings for Parameter R2 and Parameter R3 (also for Parameter P2 plus Parameter P3) does not exceed unity. After these initial settings have been made, SAM is set into operation by depressing the "Start" button to make some one of the three response lights glow. Next, the operator depresses one of the two stimulus buttons, after which the lights will all be extinguished momentarily and then some one of the three response lights will again glow and the probability dials will automatically change to three new settings totalling unity. Each time a stimulus button is depressed, the probability dials and response lights will operate again in this fashion. The machine is reset and turned off by depressing the "Stop" button.

We may most easily explain the principle underlying the operation of SAM by a numerical example that is easily generalized. Suppose, then, that at some stage in operation of SAM:

the "Parameter R" dials read .1, .3, .2;
the probability dials read .2, .3, .5; and
response light 2 is glowing.

| | |
|---|---|
| Parameter R1 | Parameter P1 |
| Parameter R2 | Parameter P2 |
| Parameter R3 | Parameter P3 |
| Response 1 | Probability 1 |
| Response 2 | Probability 2 |
| Response 3 | Probability 3 |
| Stimulus R | Start |
| Stimulus P | Stop |

FIGURE 1. SAM-23 Control Panel named SAM-23 because the capacity is *two* stimuli and *three* responses.

*This paper was presented at a meeting of the Section on January 15, 1954. A good deal of the work reported here was done while the author was employed by the RAND Corporation under project RAND of the Department of the Air Force, and later while employed by Columbia University under the Behavioral Models Project sponsored by the Office of Naval Research.

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If the "Stimulus R" button is now depressed, the sequence of events will be as follows:

(1) response light 2 ceases to glow; then
(2) the probability dials change to .32, .45, .23; and then
(3) a response light glows, determined randomly according to the probabilities .32, .45, .23.

Algebraically, and in general for a SAM-*mn* with $m$ stimulus buttons and $n > 2$ response lights, if

the old probability settings were

$p_1, p_2, \ldots\ldots, p_n$,

the new probability settings are

$p_1', p_2', \ldots\ldots, p_n'$,

the "Parameter R" settings are

$a$, $b$, and $c$, and

the "Response i" light is glowing when the "Stimulus R" button is depressed, then[5c]:

$$p_i' = [1 - (n-1)\,a - b]\,p_i + b,$$

and (2.1)

$$p_j' = \left(a + \frac{b + c - 1}{n-2}\right)p_i + \left(c + \frac{b + c - 1}{n-2}\right)p_j + \left(\frac{1 - b - c}{n-2}\right) \text{ for } j \neq i.$$

For each stimulus button there is a set of three parameter dials, for the general SAM-*mn*, and the quantities $a$, $b$, and $c$ in EQUATION 2.1 always denote the settings for the three parameter dials corresponding to the stimulus button depressed.

There seems to be little reason to go into detail concerning the actual construction of a SAM. Suffice it to say that we[5b, 6a] have made use of a SAM-29, obtained by programming an I.B.M. CPC for the purpose.

### 3. *Parameter Identification*

We are interested in determining the extent to which the behavior of SAM's may be said to resemble that of humans as learning individuals and in social groups. Our method will be to compare the behavior of man and machine under like circumstances.

As a simple example,[5b, 6a] to illustrate the general approach, we shall now consider a learning experiment with two subjects—one a human and the other a SAM-29. Each subject makes a sequence of 100 choices, each between nine alternatives, and is "rewarded" or "non-rewarded" after each choice according to some predetermined schedule—where "reward" to the human means a one-cent payment and "reward" to the SAM-29 means a depression of the "Stimulus R" button. The predetermined schedule of rewards is constructed, with the help of a table of random numbers, so that the probability of reward for each choice of alternative $i$ is $\pi_i$. This experiment is then repeated 10 times, each time with a new set of $\pi_i$ values, and the results are recorded as follows:

$$r_t^{xy} = t^{th} \text{ response on } x^{th} \text{ trial for subject } y,$$
$$s_t^{xy} = t^{th} \text{ stimulus on } x^{th} \text{ trial for subject } y \quad (3.1)$$

where

$$x = 1, 2, \ldots, 10;\ y = 1, 2;\ \text{and } t = 1, 2, \ldots, 100.$$

Let us suppose that the human subject provides his data first, and that we make use of it in choosing parameter settings for the SAM-29 so as to make the SAM's behavior as nearly like that of the human as possible.[3, 5c] We will say that the SAM-29, when operated with these special parameter settings, is "identified" with the human subject and that each is the "image" of the other. If this likeness is good enough, we might not be able to distinguish between subject and image, on the basis of data

like that in EQUATION 3.1 obtained by repeating the entire experiment, and we would be justified in claiming some success with the construction of a mathematical model for this human learning behavior.

As a more critical test of the validity of our model, we could identify two SAM's with two human subjects, on the basis of data like that of EQUATION 3.1, and then compare the behavior of the SAM's with that of the humans in a quite different stimulus-response situation. For example, a rather severe test would be provided by a two-person social interaction situation—and we consider this case in section 4.

### 4. *Stochastic Social Interaction*

There are a great many ways in which we might classify responses observed during a two-person interaction process, and many such classifications have been proposed as meaningful.[1,2] For illustrative purposes, let us assume a classification for each person such that: (a) Each of his actions is classified into one of two possible response classes, from his own standpoint; and (b) Each of his actions is classified into one of two possible stimulus classes, from the standpoint of the other person. Actually, of course, the experimenter makes all of the classification decisions.

Now an ordinary two-person interaction process seems quite complicated to analyze. There are great difficulties in coding verbal exchanges, and still greater ones in classifying non-verbal behavior. A great deal can be gained by controlling the range of responses so as to simplify the classification problem, and we shall now be interested in a gross simplification.[5a]

Specifically, our two subjects have only two buttons they can push to denote response, and two lights to glow to denote stimulus. If we name the buttons "Yes" and "No," and describe the lights as "Reward" and "Non-reward," we automatically establish the necessary correspondence between model and experiment. The interaction process is completely defined by the rules[5d] set forth in TABLE 1. For example, if Subject 1 depresses the "Yes" button and Subject 2 depresses the "No" button, then the probability is .6 that Subject 1 will next get the "Reward" light and independently .2 that Subject 2 will get the "Reward" light.

TABLE 1

INTERACTION REWARD RULES

| *Response of* | | *Probability of Reward* | |
|---|---|---|---|
| *Subject 1* | *Subject 2* | *Subject 1* | *Subject 2* |
| No | No | .2 | 1.0 |
| No | Yes | .5 | .6 |
| Yes | No | .6 | .2 |
| Yes | Yes | .4 | .5 |

The interaction experiment can be conducted using SAM's-22 in various ways, to check the extent of likeness in behavior as between SAM and image. For example, SAM and image should be rewarded with about equal frequencies when playing together symmetrically in a series of games like that defined in TABLE 1; or, the long-run behavior of two SAM's should be like that of their images when playing together in such games. Of course, more complex languages than the simple Yes-No variety used here could be introduced to provide a richer variety of interaction behavior.

### 5. *Experimental Results*

The principal experimental result thus far[5b] pertains to trials in which ten human subjects, and one SAM-29, each made 100 consecutive choices between nine alternatives on ten occasions. The average number of rewards for the ten human subjects was 78.4, as compared with 73.3 for the SAM, but the SAM was rewarded more often than were the two human subjects whose scores were 67.2 and 54.3. The SAM-29 used was chosen as the image of rats observed in

T-maze choice situations, but the parameters were not estimated with any great care.

Results obtained to date, with human subjects in two-person interaction games, are inadequate to permit any final conclusions to be drawn concerning the validity of the stochastic models for this case. The SAM-29 has had about the same success, however, in playing simple non-constant sum games (as in TABLE 1) with human subjects, as have pairs of human subjects with the same games.

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## *SECTION OF PSYCHOLOGY*

### PERSONALITY VARIABLES AND REHABILITATION*

*By* HERBERT FENSTERHEIM**

The purpose of this paper is to discuss the relationship of personality variables to the rehabilitation process. First, however, it is necessary to consider the world in which the disabled person must function.

The disabled person is confronted with a physical world in which he may be unable to cope with the simplest situation. Stairs, doors, crowds—anything—may present difficulties that are beyond him. Nor is the social world less difficult; our society does not accept the disabled. In our culture, such prejudice has a long history and these attitudes are most prevalent even today. In employment, for example, it is only during periods of manpower shortage that the disabled have a chance to become self-supporting and to gain the self-respect that goes with it. This, and similar facts have led to the consideration of the disabled as a minority group. Despite the many similarities, however, important differences exist between the two. The disabled do differ from the general population in their physical capabilities and potentialities, whereas this is not true of members of ethnic minority groups. Also, the member of a minority group is still the member of a group with all that such membership implies. The disabled are not full members of any group and tend to become social isolates and to acquire the problems of the social isolate. The resolution of these problems will depend upon social action stemming from a psychological and a sociological understanding.

Even the environment of the rehabilitation training situation may inhibit the progress of the patient. A loosely structured training environment, for example, may make it impossible for the brain-injured individual to function. Where training is long and progress is slow, even the most integrated person may form an incorrect idea of what is actually happening. It is essential to give patients as much specific information about their performances as is possible; actual measurement would be important in this respect. Further, it is important to investigate the social variables that may facilitate or inhibit rehabilitation training. Such social variables as group atmospheres, general morale, inter-patient competition, suggestibility, and the doctor-patient dyad may be considered.

There can be little doubt that personality variables do exert a marked influence upon the rehabilitation of an individual. The patients concerned must be motivated in the proper direction and must possess the ability to work constructively. During the course of the actual training, "psychological interferences" are often noted. Patients may show a "lack of motivation" or the symptoms of either depression or apathy. Various fears may be evident, such as the fear of falling when learning to ambulate, or disruptive reactions to mild pain may make progress almost impossible. The literature also notes a phenomenon that may be labeled "insistence on disability." Patients often refuse to attempt movements with limbs that had been paralyzed even though such movements may now be possible. The reluctance of patients to give up their wheel chairs when it is medically indicated that they can do so may be another illustration of the same phenomenon. In a more general approach, Barker has noted that the incidence of maladjustment is greater among the disabled than among the

*This paper, illustrated with lantern slides, was presented at a Symposium on Psychological Theory and Rehabilitation held at a meeting of the Section on January 18, 1954. The participants, besides the author of this paper, were Harry Sands of the Epilepsy Association of New York, and Herbert G. Birch of the Department of Psychology, City College of New York.

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general population. He has also noted that the longer the history of disability or the more severe the disability, the greater the degree of maladjustment.

At first approach, it would appear that the existence of a psychopathological condition in the patient would be a crucial factor. The neurotic, for example, is often unable to work constructively, often may be motivated to retain and use his physical disability. Levi has shown that patients with a large number of anatomy responses to the Rorschach cards (*i.e.*, patients who are hypochondriacally overconcerned with themselves) make poor rehabilitation candidates. Psychopathology *per se*, however, cannot be considered a negative predictor. Lakritz and Fensterheim have reported the successful physical rehabilitation of aged psychotic patients. Indeed, the existence of psychopathology may even be a facilitating influence. Levi reports that patients who show extensive "neurotic guilt" make maximal progress. The present writer has observed patients with tremendous "neurotic drive" who had surpassed the goals set for them.

The relationship of specific disabilities to certain personality types has also been investigated. At one point, there were hypothesized such entities as the "epileptic personality," the "paraplegic personality," and personality types for the blind and the deaf. However, this approach has, in general, been abandoned. It is now held that a physical disability presents a psychological stress which the individual meets with those adaptive patterns that characterize his pre-disability state. The objective aspects of the disability that are most important are the extent to which it is disruptive, the time of life in which it occurs, and its obviousness—its cosmetic effect. It is the subjective meaning of the disability, however, that is considered of greatest importance, what the disability means to the person. In this area, unfortunately, the interpretations spring mainly from theories of psychopathology rather than from a more empirical type of evidence.

The relationship between the changed physical status of the individual and his self-concept has come in for much attention. Because the individual has changed, his perception of himself must also change to reflect the new reality. Often it is found that this change is not an easy one for the patient to achieve. Many of the disabled deny the fact that they are disabled. This phenomenon was first noted among brain-injured patients and is found in its most extreme forms among such patients. However, although perhaps in a more subtle form, it is found so extensively among all forms of disabilities that one of the most frequently cited goals of rehabilitation is that of "acceptance of disability." Until the person realizes that he is disabled, he cannot take the necessary steps to minimize its disruptive aspects.

The present approach to the psychology of the disabled may, therefore, be summarized as one in which the person attempts to meet the stresses brought on by his disability through the means of those adjustive patterns and personality characteristics that have typified him prior to the disability. It is not held that the presence of the disability has a more direct effect upon the psychology of the person. This omission is believed to be a major theoretical error.

The holistic or organismic approach to a person states that the mind and the body are not two different things interacting but are two aspects of the same organism. It would be logical to anticipate that a major change in one (the body) would be paralleled by a major change in the other (the mind), for it is the entire organism that has changed. The disabled person is a different person and should be expected to have a different psychology.

Kurt Goldstein has discussed this very

point when he compared the psychology of the impaired organism with the psychology of the intact organism. The disability brings with it a shift in the motivational pattern of the individual. This shift is one of perspective rather than one of content but, nevertheless, it is of major importance. The main energies of the disabled person, according to Goldstein, are directed towards achieving and maintaining a situation in which he can function optimally. This situation is brought about, both by limiting himself and by limiting his millieu. The denial of disability previously discussed is one illustration of such a limitation. Also, when faced with a problem, the impaired person cannot meet it constructively but suffers a disruption of behavior and directs his attempts towards escape rather than towards solution. Such a change in the psychology of the person is not within the awareness of the individual and is the product of an organismic readjustment to his changed status.

The evidence in support of this theoretical position stems mainly, but not exclusively, from severely brain-injured patients. Patients with peripheral injuries have not lost the plasticity of behavior to the same extent as the brain-injured. They are better able to rationalize their behavior. They have a greater flexibility in meeting situations. Hence, it may be predicted that the signs of the organismic readjustment discussed above will not be as obvious among these individuals as among the cortically damaged. This was exactly what has been found in the investigation of the denial of disability. Even though more subtle and less easily demonstrable, such a change in the psychology of the disabled is of great significance.

The pre-disability personality of the individual retains much of its importance within this theoretical framework. The individual will use similar adjustive techniques as previously, but now these techniques are aimed at slightly different goals. Although there may be many similarities between the psychological characteristics of the organism in the pre- and post-disability states, it must be remembered that it is no longer the same organism. The disabled person must be understood in his own right and not merely as an intact person with a special type of psychological stress.

## *DIVISION OF MYCOLOGY*

### STRUCTURE AND COMPOSITION OF THE WALLS OF THE CONIDIOPHORES OF *ASPERGILLUS NIGER* AND *A. CARBONARIUS**

*By* WANDA K. FARR**

Following the description of spiral configurations in the wall of the cotton fiber by Farr and Clark,[1] the authors were informed by Doctor Charles Thom that he had observed, in the conidiophores of *Aspergillus niger*, *A. ochraceous*, and *A. flavus*, "spiral markings in the walls similar to those in the cotton fibers." Cultures of these three fungi were provided and the observation was confirmed. The crossed-spirals, slopes of the spirals, and the areas of reversal of direction in the spirals were found to be strikingly similar to those in the cotton fiber.

These structural similarities, along with the results of certain cytochemical studies, were described by Farr and Eckerson.[4] The spiral fibrils, in both the cotton fibers and the conidiophores, represent secondary deposits of cell wall materials formed in the living protoplasm. They are rich in cellulose, which brings about their double refraction in polarized light. In the young cotton fiber, the first cellulose, in intimate association with pectic material, is deposited over the entire inner surface of the primary membrane. In these three fungal cells, the first cellulose is deposited in the basal portions of the conidiophore walls, and secondary wall formation continues progressively toward the apex. While the walls of the epidermal cells, from which the cotton fibers develop, contain cellulose; in the walls of the hyphae, from which the conidiophores develop, no cellulose was detected, except for a distance of 10 to 20 microns on either side of the basal end of the condiophore.

The occurrence of considerable quantities of cellulose in the secondary lamellae of the conidiophore walls is of particular interest in view of the widespread occurrence of chitin as the so-called "structural element" in fungal tissues. Molisch, in 1913,[9] summarized the current viewpoint as follows:

"Charakteristich fur die Membran der Pilze erscheint das Chitin. Wie die Zellulose bei den meisten anderen Pflanzen das Grundgerust der Zellhant bildet, so das Chitin bei den Pilzen. Er kommt zwar Zellulose auch in vielen Pflanzenmenbran vor, aber das Chitin bildet doch in der genannten Pflanzengruppen den Hauptbestandteil der Membran."

The value of x-ray diffraction for the identification of both chitin and cellulose[2,7,8] led to an initial attempt by Farr and Clark to identify the constituents of the wall of the mature conidiophore of *Aspergillus niger* by means of this technique. Diffraction lines characteristic of chitin alone were obtained. The diffraction lines of cellulose were not in evidence, although in conidiophores from these same cultures cellulose was identified and located in the secondary wall lamellae and in the protoplasm by means of cytochemical methods and polarized light. In view of these findings, a new approach to the problem has been made involving cytochemical, x-ray diffraction, and electron microscopical studies of conidiophores of *Aspergillus niger* and *A. carbonarius* at five successive stages of development. The results obtained constitute the subject matter of this brief progress report.

Cultures of these fungi were obtained through Doctor Kenneth Raper from the type cultures maintained by Dorothy Fennell of the Northern Regional Research Laboratory. They are identified as follows:

*Aspergillus niger:* No. 4707.878 (NRRL 67); and

*This paper, illustrated with lantern-slides, was presented at a meeting of the Division on January 22, 1954.

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*Aspergillus carbonarius:* No. 248-4030 (NRRL 369).

The use of *A. niger* has provided a basis for comparison of the present results with those of our earlier investigations. *A. carbonarius* was supplied because of the large size of the conidiophores and the consequent advantage for sample preparation. Both were grown upon standard Czapek agar. Very large conidiophores were produced in the cultures of *A. carbonarius* by growing them upon sterilized corn kernels, kept rather dry at the suggestion of Doctor Raper.

Cellulose was identified upon the basis of its blue coloration after treatment with $I_2KI$ (1gm. $I_2$; 3 gm. kI; 300 cc. dist. $H_2O$) and 65 per cent $H_2SO_4$. Conidiophores are mounted in the $I_2KI$ solution upon a microscope slide and allowed to stand for approximately 10 minutes in a covered petri dish. A drop of the $H_2SO_4$ solution is then placed at the side of the cover-glass and drawn over the specimen by means of narrow strips of filter paper. The slide is then returned to the petri dish and held for future observation.

Chitin was identified by conversion to chitosan. Conidiophores are heated for three hours, in sealed tubes, with saturated KOH at 180°C., washed in 90 per cent alcohol, and treated with $I_2KI$ solution. The chitosan formed by treatment with hot alkali is colored red-violet by the $I_2KI$ solution.

The polarizing microscope was used to locate the cellulose and chitin in the untreated conidiophores. The chitin in most fungi is isotropic; cellulose is anisotropic and its presence in any part of either the protoplasm or the cell wall can be detected by means of this characteristic, unless it is heavily encrusted with isotropic substances.

The Biuret, Xanthoproteic, Millon, Eosins, and Berlin Blue Methods have been used for the identification and localization of proteins in the developing and mature conidiophores.

Callose has been localized and identified by its affinity for Lackmoid (Resorcin Blue). The conidiophore is placed in the reagent (1 part potassium ferrocyanide; 20 parts water; 10 parts acetic acid) for one hour, washed with 60 per cent alcohol and treated with a few drops of dilute ferric chloride. The callose is colored blue.

Resistance to reagents and stains may be influenced by the presence of fatty acids and the speed of reaction is increased by treatment with boiling alcoholic $K_2CO_3$ (1 per cent), ether, and 95 per cent alcohol.

X-ray diffraction analyses have been made by G. L. Clark upon *A. carbonarius* at five successive stages of development. The most mature samples used for this purpose have been taken at an early stage of spore shedding before the black *aspergillin* has stained the upper portion of the conidiophores stalk. Although secondary wall deposits were then well advanced, dense protoplasmic masses remained in the central canal.

One of the most striking characteristics of the mature conidiophores of both *Aspergillus niger* and *A. carbonarius* is their delayed reaction to cytochemical reagents. In the cotton fibers and many other types of plant cells, the reaction of the cellulose to $H_2SO_4$ and $I_2KI$ is almost instantaneous. In the mature conidiophore the same positive reaction may require two weeks. Throughout the entire period of development the cellulose reaction in the primary membrane is negative. The deep blue coloration, characteristic of cellulose in the presence of sulphuric acid and iodine-potassium iodide solutions, is confined to the protoplasm and the secondary lamellae of the conidiophore wall. Cellulose appears first in the protoplasm of the conidiophore; later it is deposited progressively from base to tip in secondary wall formation.

Delayed reaction to reagents occurs, in

some measure, in the younger as well as in the mature conidiophores. If a growing specimen is lifted, uninjured, from the culture dish to the slide, many hours may elapse before the blue coloration of the cellulose in the protoplasm and the secondary lamellae is in evidence; several days, before it is completed. From these observations we learn of the degree of resistance of the primary membrane of the conidiophore to strong sulphuric acid and realize that it constitutes an effective barrier to reagents and stains which react readily with the materials of the secondary lamellae and protoplasm.

The chemical nature of the primary membrane can be determined in the very young conidiophore as it emerges from the hypha. At this and all subsequent stages of development it is chitinous, as shown cytochemically by the chitosan reaction. The young conidiophore is composed of the primary chitinous membrane and the protoplasm rich in protein and pectic material. As growth proceeds, cellulose and callose appear first in the protoplasm and later, along with pectic material and protein, in the secondary wall lamellae. In the early period of spore discharge, the conidiophore has a thick, resistant exterior wall of chitin, secondary deposits of cellulose, callose, pectic material and protein, and a dense central core of protein pectic material, callose and cellulose. In the fully matured conidiophore the protoplasmic material is more nearly used up in secondary wall formation and the upper part of the stalk deeply stained with *aspergillin*.

During the application of the iodine and and sulphuric acid solution to the conidiophores for the identification of cellulose, there is some evidence of a very thin, rapidly hydrolyzed membrane or surface layer upon the primary wall. A pectic membrane was suspected, but this is not confirmed to date by evidence of surface staining with ruthenium red. Studies with the electron microscope by Althea Revere, now in progress, are producing some evidence of such a delicate surface covering in sharp contrast to the rigid chitinous wall beneath.

The identifications and localizations of proteins in *Aspergillus carbonarius* may be summarized as follows:

| *Protein reactions* | *Protoplasm* | *Cell wall* | |
|---|---|---|---|
| | | *Primary* | *Secondary* |
| Biuret | + | – | + |
| Millon | – | – | – |
| Xanthoproteic | + | – | + |
| Eosin | + | – | + |
| Berlin Blue | + | – | + |

From the positive Biuret and Xanthoproteic reactions, we learn that proteins with the $CONH_2$ and tryptophane groups are present; from the negative Millon reaction, that those with the tyrosine group are either lacking or present in small quantities. The staining reactions with Berlin Blue and Eosin confirm the localization of these proteins in the secondary wall and protoplasm.

The cytochemical reactions in the conidiophores of *Aspergillus niger* are essentially the same as those in *A. carbonarius* with one observed exception. When the primary wall of *A. niger* is treated with $H_2SO_4$ and $I_2KI$ it swells and becomes deep yellow in color as does insect chitin. The primary wall of *A. carbonarius* swells and remains colorless with the same reagents unless previously treated with boiling 1 per cent $K_2CO_3$, ether and 95 per cent alcohol. These differences in behavior suggest the presence of fatty acids in the primary wall of *A. carbonarius* which prevent the full action of the sulphuric acid upon the chitin.

The x-ray diffraction studies, to date, have dealt with dried, undissected, and untreated conidiophores at five successive stages of development. The x-ray diffraction patterns obtained are in keeping with the

complex structure and composition described. In passing through the conidiophores, the x-ray beam encounters chitinous primary walls, spiral configurations of the chemically heterogeneous secondary lamellae, and protoplasmic residues. As a result the background of the diffraction pattern is fogged with the amorphous pectic material and with the more or less amorphous protein. The type of diffraction produced by callose is not known since its chemical structure has not been determined.

As an example of the x-ray findings, the first results obtained with the conidiophores of *A. carbonarius* are compared with known values for chitin and cellulose:

*Sequence of $^{d}hK1$ Values*

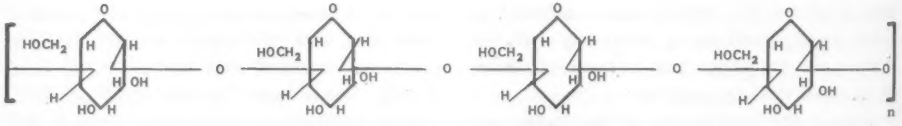
| *Stages of Development* | | | | | *Chitin* | *Cellulose* |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | | |
| 4.54 | 4.54 | 4.54 | 4.54 | 3.96 | 3.42 | 2.65 |
| 5.15 | 5.15 | 5.15 | 5.15 | 3.34 | 4.66 | 4.04 |
| 9.7 | 9.7 | 9.7 | 9.7 | 5.15 | 5.15 | 4.50 |
| | | | | 9.7 | 10.27 | 5.53 |
| | | | | | | 6.27 |

The change in spacings at the fifth stage of development may be related to the period of intensive deposition of secondary wall materials as observed in the microscopic studies. In these first x-ray diffraction patterns, the shifting of lines, disappearance of lines, and lack of conformity with either cellulose or chitin led us to ask with what kind of compounds or mixtures of compounds we were dealing. Further study has now shown that the 3.96 spacing corresponds to the 4.04 spacing of pure cellulose, and faint rings farther out correspond to the 2.65 cellulose spacing. The 3.34 and 5.15 spacings are from chitin and the 4.54 spacing probably represents an unresolved combination of 4.50 cellulose and 4.66 chitin spacings.

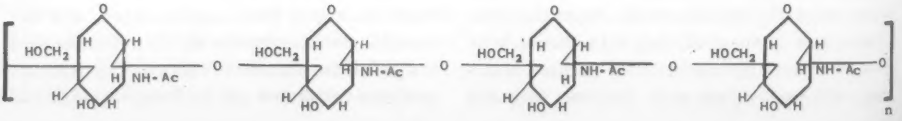
These x-ray diffraction studies of dried, untreated conidiophores serve to indicate the presence of cellulose and chitin along with proteins and large quantities of amorphous material. The current studies deal with undried, dissected, and chemically fractionated conidiophores. Such preparations should give sharper and less confused diffraction lines. In addition to *Aspergillus niger*, and *A. carbonarius*, conidiophores of *A. giganteus* are being included, because of their large size, at the suggestion of Doctor W. H. Weston.

The similarity in the unit cell structure of cellulose and chitin, as determined by x-ray diffraction, is shown in the following structural formulae:

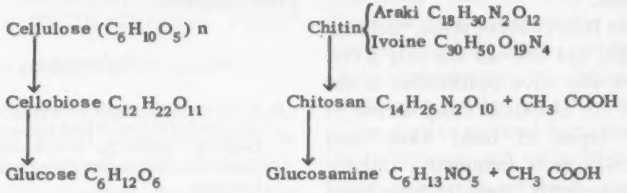
*Cellulose Unit Cell*



*Chitin Unit Cell*



The difference between cellulose and chitin, a nitrogen-containing carbohydrate, is clearly indicated in their respective degradation products:




Preparation of the degradation products of conidiophore substances in both *Aspergillus carbonarius* and *A. giganteus* are now in progress.

The significance of the findings to date and the plans for future work may be brought out by a consideration of the past work with fungal cell walls.

As early as 1811, Bracconat extracted from fungi, with hot water and alkali, a substance which he named *fongine*. Payen, in 1843, determined the nitrogen content of this extract and commented upon its failure to give the characteristic cellulose reaction with $H_2SO_4$ and $I_2KI$. He did not associate this substance, however, with the chitin which had been obtained from lobster and crayfish shells by Odier in 1823.

The intensive work with fungal cell walls began somewhat later. Richter[10] reported in 1881 that fungi do not have a special type of cellulose; that the normal cellulose in fungal membranes is encrusted with other substances—probably protein. He found that the typical cellulose reactions are obtained in these membranes when they are macerated in 7 to 8 per cent KOH for from two to three weeks, to two to three months.

De Bary[1] found true cellulose in a number of fungi (*Saprolegnia* and *Peronospora*), but considered that most fungi have a peculiar type of cellulose which he named "fungal cellulose."

Winterstein[14] reported in 1892 that fungal cell walls which do not react to cellulose reagents are composed of chitin, not cellulose. Gilson,[5] in the following year, corroborated Winterstein's findings and established the similar nature of the chitin in fungi and in the shells of arthopods. He also transformed chitin into chitosan by heating it in saturated KOH at 180°C.

Van Wisselingh[15] confirmed the findings of Winterstein and Gilson and added the observation that chitin, when treated with $I_2KI$ containing a trace of free acid, is colored red-violet. He stated that either cellulose or chitin may occur in fungal cell walls but that they do not occur together.

Mangin[6] was not able to confirm van Wisselingh's report of chitin in the mucors. His studies brought out the complex chemical make-up of the walls of fungus mycelia and also the marked variations in the walls of fruiting bodies developed from these mycelia. He found that the presence of nitrogenous and pectic compounds frequently prevents the penetration of reagents and delays the positive reactions of the cellulose which they encrust. He also described a "cutin-like" material which may have been chitin as identified by Winterstein and Gilson.

In a series of chemical studies of the hyphae of the *Fusaria*, *Sclerotinia*, and *Pythiaceae*, published from 1928 to 1942, Thomas[11,12,13] found that chitin and various fatty acids present in fungal cell walls mask the reactions of cellulose. The *Fusaria* studied contained small amounts of cellulose and relatively large amounts of chitin. Both cellulose and chitin were likewise found in *Sclerotinia* and in the *Pythiaceae*. Thomas succeeded in identify-

ing cellulose, chitin, callose, pectic material, protein, and fatty acids in the fungal mycelia studied.

Richter, de Bary, Winterstein, Gilson, van Wisselingh, and Thomas are only a few of the workers who have contributed to our knowledge of the chemical composition of fungi. Many types of fungi have been studied; mycelia most frequently, fruiting bodies less frequently. Results have been interpreted in terms of both chemical homogeneity and chemical heterogeneity. A consideration of the full accumulation of data shows, however, that the evidence weighs heavily upon the side of the chemical complexity of any type of fungal tissue. The information available furnishes a poor foundation for the frequent statement that cell walls of fungi are composed of chitin. In fact there is, at present, too little information concerning fungal cell walls to permit any generalizations concerning their structure, chemical composition, and physical properties.

Thomas has stated[11] "No theory is advanced at this time regarding the probable origin and order of development of the cell wall. More detailed study is necessary in following the process of growth before this can be done.

The present report covers our findings to date with respect to the origin and order of development of the conidiophores walls of *Aspergillus niger* and *A. carbonarius*. The work in progress covers, in addition, dissected and fractionated conidiophores of *A. carbonarius* and *A. giganteus* by means of the same techniques of microscopy, cytochemistry, x-ray diffraction, and electron microscopy.

A review of the past work with cell walls of fungi and a consideration of these present findings indicate that there is a large and fruitful field for cell wall research in this group of plants. Studies of the fundamental structural and chemical properties of fungal cell walls can be expected to show important relationships with the properties of cell walls throughout the plant kingdom.

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## *SECTION OF ANTHROPOLOGY*

### RECENT ARCHEOLOGICAL DISCOVERIES IN SOUTH COASTAL PERU*

*By* WILLIAM DUNCAN STRONG**

The river valleys of Ica and Nazca in the south Peruvian desert have long been famous from the archeological standpoint. Despite this fact, however, the region has been very poorly known from the historic standpoint. The archeological fame of this area rests mainly upon the discovery, by Max Uhle in 1901, of the colorful and unique Nazca culture there. This ancient culture is notable, particularly, for its exquisite polychrome pottery. The south coastal Peruvian region again came into prominence in 1925 when Julio Tello discovered the remarkable Necropolis and Cavernas cultures on the Paracas Peninsula slightly northwest of Ica. The Paracas Necropolis has since become world-famous because of the amazing textiles recovered from that site, while the immediately adjacent Cavernas tombs are notable for the incised and strangely painted ceramics of a specialized Chavín type which they contain. Other interesting cultures leading up to the Inca and Spanish conquests are also present. Yet, despite the known wealth and antiquity of cultural materials, their sequential or stratigraphic order, as well as their overlapping ranges, have remained largely unknown to the present time. This paradox is due mainly to the fact that the bulk of all these rich materials in museums around the world has been dug up by *huaqueros*, or treasure hunters, and lacks all provenience data. The few scientific excavations in the area have received very little publication, and none of these have been stratigraphic in their nature.

It was for this reason that the Columbia University Expedition of 1952-53 emphasized detailed stratigraphic and settlement pattern studies which yielded much new basic information on cultural sequence, range, and settlement pattern, particularly of the earlier cultural horizons. The exacting techniques and methods employed were those which, in previous years, had been successfully followed in the Central and Northern coast regions of Peru (Strong, Willey and Corbett, 1943; Strong, 1948; Strong and Evans, 1952). In the present Nazca-Ica work we were sponsored and greatly assisted by the Regional Museum of Ica and the Ministry of Education of Peru. For this wholehearted cooperation we are deeply grateful. Gratitude is also here expressed for the financial support of Columbia University and the Wenner-Gren Foundation for Anthropological Research.

The Nazca-Ica region is a unique and fascinating area which, despite great modern activity in cotton-growing and mining, is still very little known from the detailed geographic or other standpoints. Archeological remains are largely limited to the narrow, immediate river valleys (there are some eleven major branches of the Rio Grande de Nazca) and these small irrigable areas are separated by vast reaches of barren desert, high pampa, and rough, coastal mountain ranges. To the east, one encounters the high ranges of the Andes proper. Where water occurs, the atmosphere is tropical, great sand dunes with palms yield to algarobe-covered hills and then to limited plantations of cotton, grapes, figs, and other tropical fruits. But the latter areas are very limited and the major impression obtained from jeep or airplane is one of unlimited sun and empty space where time has stood still for millenia. Man, however, has been active in these oasis-like valleys for a long time and it is with this record that we are concerned here.

In this necessarily very brief synoptic

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report we will sketch in the major cultural horizons encountered by the Columbia University expedition emphasizing, particularly, the earlier civilizations about which we secured much new data. In regard to the later cultural horizons, mainly encountered in our survey work, little can be said at present since these collections have not, as yet, received intensive study. The framework of Culture Epochs here employed is basically the same as that adopted at the Chiclin Conference of 1946, but is slightly modified to accord with that of the Lima Conference of 1953, the outlines of which will be available shortly. While the entire sequence of cultural relationships is far from clear at present, particularly in the earliest and the latest periods, a general succession of major cultures is perceivable now and it is this newly revealed order which is stressed here. For this reason we will begin with the earliest known culture evidences recently discovered in this area and proceed in time to the Inca and historic period.

The earliest cultural manifestations, which we discovered, belong to the *Prehorticultural Epoch* and consist of lithic artifacts unassociated with agricultural or ceramic evidences. These materials were found in low shell heaps on the vast, desolate Bay of San Nicholas to the south of Nazca. The sand-blasted artifacts included retouched projectile points, scrapers and knives of obsidian, as well as large amounts of obsidian flakes. Shell fish, fish, and sea lions seem to have been the main sources of subsistence. The evidence obtained is limited, but definite, and the site calls for much more intensive archeological and geological investigation than we were able to give to it.

Evidence for an *Incipient Horticultural* (but pre-ceramic) *Epoch* horizon in the south is less specific but probable. It occurs in the vast shell heaps at Chavinia and, especially, at Lomas. Both are bays to the south of Nazca. At Lomas, shell heaps of vast height seem to have no pottery in their lowest levels, but do yield plant and textile fragments, possibly similar to those found in north coastal Peru at Huaca Prieta. This postulation is based on very brief examination and must be verified by major excavation. These midden sites, however, like those at the mouth of the Ica, are vast and deep and give great promise for future work.

With the *Formative Epoch,* we come into the major field of our excavation proper. Very briefly, subject to future work and analysis, we encountered three successive phases, or cultures, in this Epoch. These have been designated as *Early Paracas, Late Paracas,* and *Proto-Nazca.* The first two phases, encountered by us in the Nazca-Ica region, have been designated as "Paracas" because certain mortuary ceramic types included were first described from the Paracas Peninsula (Tello, 1929). The revised "Proto-Nazca" term usage is referred to below. The *Early Paracas* culture is known to us primarily from a burial ground at the northeastern, or upper, end of the main Ica valley. These graves contained large, plain-ware ollas, small incised vessels with fugitive red, yellow, and green powder applied after firing; and small, open orange-and-black negative-painted vessels. Other *Early Paracas* ceramic types included slipped-red and interior-incised ware. "Cavernas"-type deformed skulls occurred, but skeletal remains and other artifacts were in very poor condition. No house types or settlement patterns were observed during our brief investigation of this site. All later ceramic types, however, were absent from these graves.

The *Late Paracas* culture phase was encountered in burials at Ocucaje, and in refuse heaps and house structures at Cahuachi in the Nazca drainage. At the latter site rectangular wattle-and-daub houses of the *Late Paracas* culture were found under-

lying Nazca ceremonial structures and refuse. These Paracas houses were strongly built and, in ruined condition, formed the nuclear cores around which the southwest trade winds had accumulated large mounds upon which the *Florescent, Middle Nazca,* had later built ceremonial structures of large, conical adobes. The *Late Paracas* people had post-fired, incised, and resin-painted ceramics (a rare type in refuse heaps which occurs sparsely from *Late Paracas* to *Early Nazca* times); white-slipped ware (seemingly of the so-called "Necropolis" type which has a distribution like the above and hence seems contemporary with it); negative ware; incised interior ware; and white-and-red patterned ware. At Ocucaje, burials containing *Late Paracas* types of pottery, as well as basketry, feather work, and other artifacts, were relatively shallow with pole or stone-slab grave coverings. Large mound structures of massed reeds, walls of small conical adobes, and wattle-and-daub structures also occur in this period. The Paracas culture burial situation at Cahuachi is puzzling for while a few Paracas-type skeletal remains, a great cache of textile grave-wrappings, and extensive house and refuse deposits occur, no Paracas (*i.e.*, "Necropolis" or "Cavernas") burial ground was encountered. It is possible that the honored Paracas culture dead were prepared here and carried for burial to Ocucaje, or to the sea on the Paracas peninsula. This is a fascinating problem future research may well resolve.

The third phase of the *Formative Epoch* is newly defined for the southern region. This is here termed the *Proto-Nazca* phase, and, in ceramics, includes Cahuachi polychrome incised; a remarkable polished black-on-black or "stylus"; and polished black incised wares. These types predominate in this phase but are shared with the preceding and subsequent culture phases and seem to be transitional between the earlier Paracas and the later Nazca artistic traditions. Hence, the term Proto-Nazca seems more fitting here than as originally applied to the full-blown *Middle Nazca* (Nazca A) style at Ocucaje (Kroeber and Strong, 1924).

The *Florescent Epoch* in south coastal Peru is marked, among other things, by the establishment of the famous Nazca polychrome ceramic tradition and by great architectural activity. The earliest Nazca phase has here tentatively been designated *Early Nazca* and is characterized particularly by a newly defined ceramic ware termed Cahuachi polychrome. This type is very similar to, but simpler than, the slightly later Nazca A ware. Since it represents the attainment of controlled polychrome painting, however, as opposed to the incised and experimental painting techniques of the preceding phases, it would seem to merit inclusion in the Florescent Epoch. This ware, along with fine textile fragments, predominated in a wattle-and-daub compound of rooms, platforms, and conical adobe walls at Cahuachi, and, stratigraphically, would seem to mark the beginning of what we have here called the *Florescent Epoch.* This remains to be fully demonstrated, however. The Middle Nazca period is characterized by a fine polychrome ware which is generally similar to the Nazca A of Gayton and Kroeber (1927). In technique, application of color, control of design, and somber richness this seems to be a truly classical ceramic style. Stratigraphically, it directly overlies all types so far discussed and, in the largest temple and pyramid complex at Cahuachi, is strongly predominant.

The third culture phase as Cahuachi, the *Late Nazca* period, is characterized by a more flamboyant ceramic style which, in general, agrees with the Nazca B of Gayton and Kroeber (1927). We excavated numerous Cahuachi graves characterized by this *Late Nazca* ceramic type but the type is almost entirely lacking in the structures and

stratigraphic trenches which we excavated there. Nevertheless, Nazca B ceramics are abundant in graves and surface collections at Cahuachi and the type seems to characterize the limited decorated ware which was secured in the test trenches at the "Wooden Stone Henge" or *Estaquería* nearby. However, the complex artistic, ceramic, architectonic, and mortuary range of the complete *Florescent* Nazca period must be analyzed and discussed elsewhere.

In regard to Cahuachi, it should be noted that this site gives every indication of being the great Nazca capital throughout the *Florescent Epoch*. No other site we encountered compares with it in size and complexity.

Following the pure Nazca period, we encountered sites where this style had degenerated and some blending had taken place with Tiahuanacoid and, probably, other cultures. This, by our earlier definition (Strong, 1948), brings us into the *Epoch of Great Fusion*. Our main excavation in this period was at a site on the Taruga river designated as Huaca del Loro. At present Huaca del Loro seems a good local cultural designation for the latest, *mixed*, Nazca culture. Here occurred a round temple structure, large stone enclosures and elaborate, but looted tombs. It is a one-period site marked by two strains of pottery one of which was very late Nazca (Nazca Y of Gayton and Kroeber, 1927), and the second is of somewhat *Tiahuanacoid* strain which may have been derived from Huari to the northeast. In addition, numerous other sites were encountered where definite *Epigonal* and *Tiahuanacoid* ceramic and related styles occurred. These include great towns, or even cities, usually located on rugged talus slopes and characterized by great rough stone enclosures and thousands of rooms. The burials of this epoch are often large and contain considerable metal work which, with the exception of some gold, is lacking in the earlier periods.

The fading Nazcoid and Tiahuanacoid cultures in the Nazca-Ica region are superseded by local cultures which have been variously designated as *Ica* or *Chincha*. The latter name applies specifically to the powerful Chincha Confederacy of that and adjacent valleys which was proto-historic and pertains to the newly designated *Epoch of Kingdoms and Confederations*. These later art styles are highly conventionalized, and distinctive as are the numerous towns, temples, and cemeteries of this period. However, like the sites of the following *Imperial Epoch* marked by conquest of the region by the Incas, these later sites, which we surveyed but did not excavate, may only be mentioned here. It must be remembered that this is only a "work in progress" report. Much remains to be accomplished in this culturally rich and very complex area of higher New World civilization but, at least, the sequential outlines of some six or more millenia of cultural change and development are now beginning to assume some sort of clarity.

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# PEASANT CULTURE IN INDIA AND MEXICO: A STUDY IN CONTRAST*

*By* OSCAR LEWIS**

In the past ten years, following the establishment of the Point Four and other action programs dedicated to raising the standards of living in the under-developed countries, there has been an increasing recognition of the need for a better understanding of peasant societies. Anthropologists, in particular, have been giving more attention to peasant societies in recent years, in contrast to their earlier, almost exclusive concern with tribal societies. This new interest has been on both the practical and theoretical level. Anthropologists have participated directly in action programs as administrators, consultants, and research workers, and have helped train specialized technical personnel for foreign assignments. At the same time, they have also begun to reexamine the concept "peasant society" and the typologies in which it appears, such as the folk-urban typology, in the light of more recent research experience. A series of articles on the nature of the folk or peasant society has appeared in professional journals within the past few years.[1, 2, 3, 4]

In this paper I want, briefly, to compare my findings on the north-Indian village of Rani Khera and the Mexican village of Tepoztlan in order to illustrate: (1) the wide range of cultural forms possible under the rubric peasant society; (2) how a study of a single village in each country can give one a feeling for differences in national problems; (3) how first hand comparative research by the same investigator in different parts of the world can lead to more refined insights and thereby contribute to the strengths inherent in the comparative method.

Tepoztlan is a Catholic village of about 3,500 people, fifteen miles from Cuernavaca, the State capital, and sixty miles south of Mexico City. It is an ancient highland village which has been continuously inhabited for about two thousand years. Two languages are spoken in Tepoztlan, Spanish and Nahuatl. About half of the people are bilingual and the other half speak only Spanish.

Rani Khera is a Hindu village of 1100 people about fifteen miles from Delhi, the national capital. It is an old village which was conquered about 750 years ago by the Jats, an ethnic group which is now the dominant caste in the village. The language spoken is a local dialect of Hindi. Only a few people speak English.

Both villages may be designated as peasant societies in the sense that both are old and stable populations with a great love of the land, both depend upon agriculture; both are integrated into larger political units, such as the state and the nation, and are subject to its laws; both exist side by side with cities and have been exposed to urban influences for long periods of time; and both have borrowed from other rural areas as well as urban centers, but have managed to integrate the new traits into a stable culture pattern. Moreover, both communities exist by a relatively primitive technology and depend upon hoe culture as well as plow and oxen in agriculture; both produce primarily for subsistence but also participate in a money economy; both also use barter; both are poor, have a high incidence of illiteracy, a high birth rate and death rate, and finally, both communities have lived under foreign domination for long periods in their history and have developed that peculiar combination of dependence and hostility toward government which is so characteristic of colonial peoples.

So much for the broad similarities. Now let us summarize some of the differences.

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The settlement pattern of Rani Khera, or rather the absence of pattern, contrasts sharply with Tepoztlan. In Rani Khera, unlike the Mexican village, there is no grid pattern of streets, no village center, no plaza or market place, no government buildings. There is a greater density of population, a greater crowding of houses, a housing shortage, a shortage of space for livestock, and a marked separation of the sexes whereby many families have two separate houses, one for the women and children, another for the men and cattle.

Agriculture in Rani Khera is much more intensive and varied than in Tepoztlan; 90 per cent of the total land area is under cultivation as compared to 15 per cent. Tepoztlan depends primarily upon a single crop, corn, whereas Rani Khera has a variety of crops, including wheat, millets, sugar cane, gram, and hemp. Unlike Tepoztlan, which has no irrigation and produces only one crop a year, Rani Khera grows two crops a year on about one-fifth of its lands which are irrigated by wells and canals. But Rani Khera has practically no grazing land and forest land while Tepoztlan is rich in forest land which constitute about 50 per cent of its total resources.

In Tepoztlan, over 90 per cent of the 853 families engage directly in agriculture as cultivators, as compared to only 53 per cent in Rani Khera and most of the latter belong to a single caste. This makes for a fundamental difference in the social and economic structure of the two communities. In Tepoztlan, the family is a more self-sufficient unit free to engage in a variety of activities and occupations, and cherishes its independence from others. In Rani Khera the specialization of occupations along caste lines makes for a greater dependence of the villagers upon one another, a dependence institutionalized along hierarchical lines in the semi-feudal jajmani system. Rani Khera, therefore, has a much larger non-farm population with many aspects of a rural proleturiat.

Population pressure on the land is much greater in Rani Khera than in Tepoztlan. The former has only three-fourths of an acre of cultivable land per capita, as compared to 1.5 acres per capita in Tepoztlan. Moreover, Tepoztlan has an additional eight acres of forest lands per capita whereas Rani Khera has none.

Both villages have communally owned and privately owned lands but the functions and proportions of each are quite different. In Tepoztlan, about 80 per cent of all the land is communally held as compared to one per cent in Rani Khera. In both cases, communal lands have been a source of great strife.

In Tepoztlan, only about 36 per cent of the families have private holdings as compared to 52 per cent in Rani Khera. But, while the landless families of Tepoztlan have access to the rich resources of the communal lands, the landless of Rani Khera have no other resources. The size of holdings show fundamental similarities in both communities. Holdings are small. In both cases over 50 per cent of the holdings are less than five acres; 70 per cent are less than ten acres; 90 per cent are less than twenty acres. The range in the size of holdings is also remarkably similar, from less than one acre of which there are many, to fifty acres of which there is one in each community. It is also interesting to note that in both communities the farmers considered that ten acres was a minimal sized economic unit for a family.

One of the outstanding differences in the economies of the two communities is the much greater importance of livestock in the case of Rani Khera. In Tepoztlan there is relatively little livestock and most of it is of poor quality. By contrast Rani Khera supports a remarkably large amount of livestock, with practically no grazing resources.

*Social Organization*

It is in the field of social organization that we find the most striking differences between these two peasant societies. Indeed, they seem like separate worlds and, in retrospect, Tepoztlan seems much less complicated and much more familiar, very western-like and almost North American.

The distinctive aspects of the social organization of the village of Rani Khera as compared with Tepoztlan are: (1) the presence of a caste system; (2) the much more pervasive role of kinship; (3) the weakness of the village as a community; (4) the existence of fairly stable factions within the castes and the important positive role of these factions in the life of the village;[3] (5) the institutionalization of inter-village networks along caste lines. A few of these points are discussed below.

(1) *The caste system.* In Rani Khera, the caste system organizes life in terms of hierarchical principles and plays up status differences between groups. In Tepoztlan, the absence of a caste system makes for a much more democratically organized society. The village of Rani Khera is dominated by a single caste, the Jats, who own all the land, including the housesites of other castes. The village is officially known as a Jat village and even the formal division of the village into two *pannas* each with its lambardar or headman, is solely in terms of the Jats. The lower castes tend to live on the outskirts of the village.

Perhaps the greatest change in the caste system in the village is in relation to occupations; *i.e.*, caste and occupation are no longer synonymous. For example: some of the Jats, who are traditional agriculturists, have taken other occupations and jobs; the Brahmins are occupancy tenants of the Jats and no longer carry on their priestly functions; the Chamars have practically left their traditional work as leather workers. Other changes have also occurred, such as the refusal of the Chamars to skin dead animals, the attendance of lower caste village children in the local school, and the election of Harijans or untouchables to the newly created inter-village council or panchayat.

Despite these changes the caste system remains strong in the village. There are still separate wells for the Harijans, inter-caste dining and smoking between lower and higher castes is still taboo, low-caste persons will never sit on the same cot with high caste persons, and when government officials come to the village and call meetings to explain the new community development projects, the Harijans may attend but they stay off to one side and "know their place."

In Tepoztlan the picture is very different. No one group dominates the life of the village. Each family, whether rich or poor, owns its house and housesite, enjoys status as a villager, and can proudly say, "This is my village." The quality of inter-personal relations among Tepoztecans is comparable to what exists within the single caste of Jats; *i.e.*, status differences are played down and, whether rich or poor, respect is shown.

(2) *The role of kinship.* In Rani Khera, kinship plays a major role in the ordering of human relations. The extended family is strong. In Tepoztlan, kinship is a much less pervasive force; the nuclear family predominates, the extended family is weak, and social relations and social solidarity are organized around religious, economic, political, and other non-kinship symbols. The independence and strength of the nuclear family of Tepoztlan makes for an atomistic quality in social relations. The larger units, such as the *barrio*, the village, and the *municipio*, are relatively impersonal and do not impinge as directly upon the life of the individual as does the extended family, the faction, and the caste, in Rani Khera.

(3) *The village as the community.* In Tepoztlan, the village and the community are synonymous and community spirit is relatively well developed, at least on the verbal level. There are village leaders and village heroes. Neighboring villages are often looked down upon as inferior and are characterized by derogatory terms, such as, "dull-heads," "assassins," and "backward." In Rani Khera, the castes divide the village and weaken the sense of solidarity. Within the castes, the factions further split the village and leadership is in terms of factions. Village-wide leadership hardly exists. There also seems less readiness to delegate authority to leaders in Rani Khera than in Tepoztlan, and there is less of a *caudillo* spirit.

The difference in the sense of community is also reflected in the much stronger development of local government in Tepoztlan, with its formal election of the village president, aldermen, and other officials; as compared to the traditional informal caste panchayats which govern Rani Khera and cut across villages.

The difference in the role of the village as a community can most effectively be illustrated by a comparison of marriage. In Tepoztlan, over 90 per cent of the marriages occur within the village and 42 per cent within the *barrios* of the village. The single important rule in marriage is not to marry a close relative. In Rani Khera, the question of whom one can marry is much more complicated and is controlled by a combination of four factors, namely; caste endogamy, village exogamy, limited territorial exogamy, and gotra or sib exogamy. The 266 married women living in Rani Khera came from about 220 separate villages at distances ranging up to forty miles. Similarly, 220 daughters of Rani Khera married into about 200 separate villages. Thus, the small village of Rani Khera is the locus of affinal ties with over 400 other villages! This makes for a kind of rural cosmopolitanism which is in the sharpest contrast with the sense of the village as an isolate in Mexico. The quality of inter-village relations is also very different. In Rani Khera, inter-village relations result primarily from affinal and consanguinal ties, with religious pilgrimages ranking a low second, and trade a low third. By contrast, in Tepoztlan, inter-village relations are based primarily upon trade, secondarily on religious ties, and lastly upon kinship.

*The People*

Finally, we come to a brief comparison of the people in both villages. I have noted elsewhere that Tepoztecans are a reserved, constricted people who tend to view other human beings as dangerous and the world in general as hostile.[6] Children are required to be obedient, quiet, and unobtrusive and parents play upon children's fears to maintain control. There is a certain pervading air of tension and fearfulness among Tepoztecans; the individual and the small biological family seem to stand alone against the world.

Despite the much smaller size of Rani Khera, one has the impression that there are more people there. Crowds gather easily around the visitor and follow him down the narrow streets and in and out of houses. One rarely sees a solitary figure, children play boisterously in large groups, men chat and smoke hookah pipes in groups, women go to the well or collect cow dung together. The low value placed upon privacy in Rani Khera is in marked contrast with Tepoztlan where privacy is so valued that one gets the feeling of an apartment house psychology in this ancient village.

Faces are different in the two villages. In Tepoztlan, outside the home, faces are generally unsmiling, unrevealing masks. In Rani Khera faces seem more secure. Children are more open-faced and laughing, old men are bland and peaceful, young men restless but unrebellious, women straight and proud. Here, too, there is individual reserve

and formalized behavior but it does not seem to mask so much of an undercurrent of hostility and fear as in Tepoztlan.

The women of Rani Khera work even harder than the women of Tepoztlan but they appear less drab and bemeaned. They seem strong, bold, gay, and sharp-tongued. Their skirts and head scarves are brilliantly colored, and spangled with rhinestones and mirrors. Heavy silver jewelry on their ankles, wrists, and necks seem to validate their worth as women. Even with their faces modestly covered, the women of Rani Khera seem more independent than Tepoztecan women and have less of a martyr complex. This greater independence may be related to the fact that, for the most part, the men and women live separate lives, coming together briefly for meals, some types of work, and procreation.

### *Conclusions*

In conclusion, I believe our comparative data from these two villages demonstrates the wide range of culture that can exist in peasant societies. On the whole, the similarities are greatest in material culture, level of technology, and economics; and the differences are greatest in social organization, value systems, and personality. In terms of raising the standard of living the problems seem much the same, for the bulk of the population in both villages are poor, illiterate, landless, and live so close to the survival margin that they cannot afford to experiment with new things and ideas. When I worked in Mexico I was quite overwhelmed by the poverty of the people, their problems, and the many obstacles toward achieving the better life envisioned by their leaders. But, after a year in India, Mexico's problems seem to dwindle by comparison. The poverty of the Indian people seemed so much greater and the agrarian problem so overwhelming and complex as to defy any easy solution even on the theoretical level. Of course, in making comparisons between Mexico and India we must remember that they are in different stages of evolution in terms of their nationhood. Mexico has had its political independence for almost 150 years and has lived through the great Revolution of 1910-20, while India has only recently gained its freedom and has not had the equivalent of the Mexican agrarian revolution. These broad differences are reflected in many ways in our two villages under study.

In stressing the range of variation possible under the rubric of peasant society, I do not intend to suggest that the concept, peasant society, is not meaningful or useful as a classification for comparative research. It is not sufficiently predictive in regard to cultural content, however, to take the place of knowledge of concrete reality situations, especially in planning programs of culture change. We need more refined sub-classifications of peasant societies in terms of regional differences within countries. Only after such studies are available will we be in a position to seek for broader generalizations about the dynamics of peasant culture. It would also be useful to develop typologies on particular aspects of a society or culture rather than solely in terms of the entire society.

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## *SECTION OF OCEANOGRAPHY AND METEOROLOGY*

### THE ATLANTIC WEATHER PATROL*

*By* CHARLES R. NELSON**

The U. S. Weather Bureau provides meteorological equipment, supplies, and observing personnel aboard U. S. Coast Guard cutters which are stationed at strategic points in the North Atlantic Ocean. The United States mans five and two thirds of of the stations in the western half of the Atlantic as part of an international program in which Canada and most of the western European countries also participate.

Each ship remains on an ocean station for 21 days. Another ship then relieves it for a like period. During the period on station, the four Weather Bureau observers aboard the vessel take surface weather observations every three hours, rawins (winds aloft observations) every six hours, and radiosonde observations every twelve hours. The Coast Guard cooperates in making observations possible, especially in the use of the ship's air-search radar for tracking reflectors attached to balloons for determining winds aloft. The ship's dead reckoning tracer is used to evaluate the sounding.

The Coast Guard also provides radio beacon services and aircraft communications. The ships are effectively located for search and rescue operations.

*This statement is based on the introduction to a 16 mm., silent, color film shown at a meeting of the Section on January 26, 1954. This film is available for showing to interested groups and requests for this purpose should be addressed to: Weather Bureau Regional Office, Federal Building, N. Y. International Airport, Jamaica 30, N. Y.

A paper entitled "The World Meteorological Organization," by A. S. Kusaman, was also presented at the same meeting. No abstract of this paper has been received.

**Port Supervisor, Atlantic Weather Patrol, U. S. Weather Bureau.

# *CONFERENCES HELD*

## SECTION OF BIOLOGY

### "TISSUE CULTURE TECHNIQUE IN PHARMACOLOGY"

JANUARY 14, 15, AND 16, 1954

The Section of Biology, in cooperation with The Tissue Culture Association, Duke University, held a Conference on "Tissue Culture Technique in Pharmacology." Doctor C. M. Pomerat of The University of Texas–Medical Branch, Galveston, Texas, and Doctor Elmer L. Sevringhaus of Hoffman-La Roche, Inc., Nutley, N. J., were the Conference Co-Chairmen in charge of the meeting.

The program consisted of the following papers:

*Thursday, January 14*

PURE STRAIN, LONG TERM, AND MASS CULTURE METHODS. COMMERCIAL AND SYNTHETIC MEDIA. VIROLOGY

*Morning Session.* Chairman: C. M. Pomerat

"Responses of a Variety of Normal and Malignant Cells to Continuous Cultivation and Some Practical Applications to the Biology of Disease," George O. Gey, Frederic B. Bang, and Margaret Gey, Johns Hopkins University, Baltimore, Maryland.

"Certain Factors Limiting the Size of the Tissue Culture, and the Development of Massive Cultures," Wilton R. Earle, Jay C. Bryant, and E. L. Schilling, National Cancer Institute, Bethesda, Maryland.

"Studies of Certain Defined Media for Testing Proliferation in Replicate Tissue Cultures," Virginia J. Evans, Jay C. Bryant, Katherine K. Sanford, and Wilton R. Earle, National Cancer Institute, Bethesda, Maryland.

"Chemically Defined Synthetic Nutrients for Tissue Cultures for Pharmacological Studies," Philip R. White and Charity Waymouth, Roscoe B. Jackson Memorial Laboratory, Bar Harbor, Maine.

*Afternoon Session.*

"Certification of Commercial Media," Keith R. Porter, Rockefeller Institute for Medical Research, New York, N. Y.

"Mass Culture Methods with Special Emphasis on the Growth of Suspended Cells in Agitated Fluid Media," Olga V. H. Owens and George O. Gey, Johns Hopkins University, Baltimore, Maryland.

"The Application of Mammalian Cells in Continuous Culture for Assays in Virology," Jerome T. Syverton and William F. Scherer, University of Minnesota, Minneapolis, Minnesota.

"The Application of Tissue Cultures to the Preparation and Assay of Viral Antibodies," John F. Enders, The Children's Medical Center, Boston, Massachusetts.

*Motion Picture Session.*

"Recherches Expérimentales sur le Chondriome," J. Frederic, University of Liége, Liége, Belgium.

"Drug Action on Cells *in Vitro*," Mrs. Hans Lettré, University of Heidelberg, Heidelberg, Heidelberg, Germany.

"Activities and Responses of Living Cells and their Components as Recorded by Cine Phase Microscopy," George O. Gey, Peter Sapranauskas and Emil Borysko, Johns Hopkins University, Baltimore, Maryland.

*Friday, January 15*

SPECIAL ASSAY TECHNIQUE: COMPARISON BETWEEN *IN VITRO* AND *IN VIVO* RESULTS

*Morning Session.* Chairman: Elmer L. Sevringhaus.

"Short Term Cultures for Drug Assays–General Considerations," C. M. Pomerat and Chauncey D. Leake, University of Texas - Medical Branch, Galveston, Texas.

"Assay of Carcinolytic and Carcinostatic Agents," John J. Biesele, Sloan-Kettering Institute for Cancer Research, New York, N. Y.

"Metabolic and Chemotherapeutic Investigation of Human Glioblastoma," Margaret R. Murray and Edith R. Peterson, College of Physicians and Surgeons, Columbia University, New York, N. Y.

"A Comparison of *in Vivo* and *in Vitro* Tests for Antineoplastic Activity of Eight Compounds," Paul A. Eichorn, K. V. Huffman, J. J. Oleson, S. L. Halliday, and J. H. Williams, Lederle Laboratories Division, American Cynamid Company, Pearl River, N. Y.

*Afternoon Session.*

"The Effect of Hormones and of Vitamin A on Organ Cultures," Honor B. Fell, Strangeways Research Laboratory, Cambridge, Eng.

"Further Studies on the Inhibition of the Cytopathogenic Effects of Poliomyelitis Viruses in Tissue Culture by Antibiotic M-8450," Robert N. Hull, Eli Lilly Company, Indianapolis, Indiana.

"Cellular Sensitivity to Drug Action in Short Term Tissue Cultures *in Vitro* - Correlation with Sensitivity *in Vivo*," Jean Verne, University of Paris, Paris, France.

"The Application of Tissue Culture Technique in Dermatologic Research," Clarence S. Livingood and Funan Hu, Henry Ford Hospital, Detroit, Michigan.

*Saturday, January 16*

THE ACTION OF CHEMICAL AGENTS ON CELL ORGANOIDS AND MITOSIS

*Morning Session.* Chairman: Chauncey D. Leake

"Nuclear and Cytoplasmic Organoids in the Living Cell—An Introduction," William R. Duryee, National Cancer Institute, Bethesda, Md.

"Antibiotic Effect on Survival of Microorganisms in Tissue Culture," Hinton J. Baker, Harvard School of Public Health, Boston, Mass.

"Action of Various Substances on the Chondriosomes of the Living Cell," J. Frederick, University of Liége, Liége, Belgium.

"Synergists and Antagonists of Mitotic Poisons," Hans Lettré, University of Heidelberg, Heidelberg, Germany.

*Afternoon Session.*

"Mitotic Effects of Certain Amino Acid Analogs in Tissue Culture," John J. Biesele and J. A. Jacquez, Sloan-Kettering Institute for Cancer Research, New York, N. Y.

"Inhibition of the Colchicine Effects on Mitosis," H. H. Benitez, M. R. Murray, and E. Chargaff, College of Physicians and Surgeons, Columbia University, New York, N.Y.

"The Effects of Some Stimulants and Depressants on Individual Fibroblasts in a Perfusion Chamber," (Film) Ralph Buchsbaum and Joseph A. Kuntz, University of Pittsburgh, Pittsburgh, Penn.

"Quantitative Cine Analysis of Activity in Cell Organoids," C. M. Pomerat, University of Texas—Medical Branch, Galveston, Texas.

"RECENT ADVANCES IN THE STUDY OF THE STRUCTURE, COMPOSITION, AND GROWTH OF MINERALIZED TISSUES"

JANUARY 22 AND 23, 1954

The Section of Biology held a Conference on "Recent Advances in the Study of the Structure, Composition, and Growth of Mineralized Tissues." Doctor Roy O. Greep of the Harvard School of Dental Medicine, Boston, Mass., and Doctor Albert E. Sobel of The Jewish Hospital of Brooklyn, Brooklyn, N. Y., were the Conference Co-Chairmen in charge of the meeting.

The program consisted of the following papers:

*Friday, January 22*

*Morning Session.* Chairman: Milan A. Logan

"Microstructure and Histochemical Characteristics of the Mineralized Tissues,"

Reidar F. Sognnaes, Harvard School of Dental Medicine, Boston, Mass.

"Electronmicroscopy of Tooth Substance," David B. Scott, National Institutes of Health, Bethesda, Md.

"The Chemical Nature of the Organic Matrix of Dentine, Enamel and Bone," Maurice V. Stack, Guy's Hospital, London, England.

"Submicroscopic Interrelationships of Matrix and Crystal Formation," Robert A. Robinson, University of Rochester, School of Medicine and Dentistry, Rochester, N. Y.

"Formation of Bone and Teeth as Visualized by Radioautography," Charles P. Leblond and Richard C. Greulich, McGill University, Montreal, Canada, and Leonard F. Belanger, University of Ottawa, Ottawa, Canada.

*Afternoon Session.* Chairman: A. Baird Hastings

"The Nature of the Bone Salt," Sterling B. Hendricks, Department of Agriculture, Washington, D. C.

"Solubility Characteristics of Dentine, Enamel, and Bone," Harold C. Hodge, University of Rochester, School of Medicine and Dentistry, Rochester, N. Y.

"Radio Tracer Studies of Hard Tissues," Wallace D. Armstrong, University of Minnesota, Minneapolis, Minn.

"Recrystallization in Bone," William F. Neuman, University of Rochester, School of Medicine and Dentistry, Rochester, N. Y.

"X-ray Diffraction of Biological and Synthetic Apatites," Otto Trautz, New York University, School of Dentistry, New York, N. Y.

*Saturday, January 23*

*Morning Session.* Chairman: Roy O. Greep

"Local Factors in the Mechanism of Calcification," Albert E. Sobel, The Jewish Hospital of Brooklyn, Brooklyn, N. Y.

"Effect of Nutritional Factors on Bones and Teeth," James H. Shaw, Harvard School of Dental Medicine, Boston, Mass.

"Hormonal Influences on Skeletal Growth," Lawson W. Wilkins, Johns Hopkins University, School of Medicine, Baltimore, Md.

"The Role of the Parathyroids in Calcium and Phosphorus Metabolism," Paul L. Munson, Harvard School of Dental Medicine, Boston, Mass.

*Afternoon Session.*

Panel Discussion with the following participants:

*Moderator:* Albert E. Sobel.

*Panel:* I. Fankuchen, Polytechnic Institute of Brooklyn, Brooklyn, N. Y.; A. Baird Hastings, Harvard Medical School, Boston, Mass.; Harold C. Hodge, University of Rochester, School of Medicine and Dentistry, Rochester, N. Y.; Milan A. Logan, University of Cincinnati, Cincinnati, Ohio; Franklin McLean, University of Chicago, Chicago, Ill.

These conferences are provided for active workers in special fields represented. Attendance is limited to those invited to participate in these conferences and to interested Members of the Academy.

# *NEW MEMBERS*

*Elected January 28, 1954*

## LIFE MEMBERSHIP

Lott, Mary Harriet, B.S., Medicinal Chemistry. Research Chemist, Oklahoma Medical Research Foundation, Oklahoma City, Okla.

## SUSTAINING MEMBERSHIP

Beck, Lawrence T., Civil Engineering. Partner, Edwards, Kelcey and Beck, New York, N. Y.

McCoy, Francis W., M.D., Collagen Diseases. Resident in Medicine, Hospital for Special Surgery, New York, N. Y.

Severgnini, Alberto P., LL.D., Research. Business Executive, New York, N. Y.

## ACTIVE MEMBERSHIP

Appell, William Theodore, Ph.D., Psychosomatic Research. Research Assistant, Columbia University, College of Physicians and Surgeons, New York, N. Y.

Arlet, Jacques, M.D., Medicine. Assistant des Hôpitaux, Toulouse, France.

Atkinson, Walter, M.D., General Surgery. Associate Professor of Surgery, Georgetown Medical School, Washington, D.C.

Auerbach, Herman L., M.D., Medicine. Hazleton, Pa.

Auskaps, Aina M., D.D.S., Dentistry and Biochemistry. Student, Harvard School of Dental Medicine, Boston, Mass.

Bachrach, Howard L., Ph.D., Microbiology. Biochemist, U. S. Department of Agriculture, Plum Island Animal Disease Research Laboratory, Greenport, L. I., N. Y.

Bader, Fritz E., Organic Chemistry. Research Chemist, Ciba Pharmaceutical Products Inc., Summit, N. J.

Badin, Jacques C., M.D., Clinical Biochemistry. Fellow, New York University Medical College, New York, N. Y.

Baer, Alfred, M.D., Internal Medicine. Washington, D.C.

Baker, Charles Albert, Ph.D., Biochemistry, Microbiology. Director of Biology Section, Penniman and Browne Inc., Baltimore, Md.

Bard, Raymond C., Ph.D., Microbiology. Head, Microbiology Section, Research and Development Division, Smith, Kline and French Laboratories, Philadelphia, Pa.

Barker, Graham, B.S., Agricultural Chemicals. Chief Chemist, Diamond Alkali, Organic Chemicals Division, Newark, N. J.

Beckfield, William John, M.D., Pathology. Instructor in Pathology, Graduate Hospital, University of Pennsylvania, Philadelphia, Pa.

Benson, Walter R., M.D., Medicine. Instructor in Pathology, Duke University, Durham, N. C.

Bergstrom, William H., M.D., Pediatrics, Biochemistry. Instructor in Pediatrics, Syracuse University, Syracuse, N. Y.

Berkut, Michael K., Ph.D., Biological Calcifications. Assistant Professor of Biological Chemistry and Nutrition, University of North Carolina, Chapel Hill, N. C.

Berris, Robert F., M.D., Metabolism. Denver, Colo.

Bien, Saul M., D.D.S., Orthodontics. New York, N. Y.

Billings, Arthur A., M.D., Internal Medicine, Hematology. Senior Medical Resident, Michael Reese Hospital, Chicago, Ill.

Birkeland, Steffen, M.D., Surgery. Research Fellow in Surgery, Medical College of Virginia, Richmond, Va.

Blanc, William Andre, M.D., General Pathology. Research Fellow, Department of Pathology, Children's Hospital, Boston, Mass.

Bobalik, George Robert, M.S., Virology. Virologist, Armour Pharmaceutical Center, Bradley, Ill.

Boesch, John, Civil Engineering. Designer, Construction and Maintenance Department, Esso Standard Oil Company, New York, N. Y.

Botts, Adelbert Kenneth, Ph.D., Geography. Professor of Geography, State Teachers College, Trenton, N. J.

Brenon, Herbert C., Ph.D., Microbiology, Biochemistry. Director and Owner, Brenon Laboratory, Inglewood, Calif.

Bunge, Raymond G., M.D., Male Infertility. Professor of Urology, University Hospitals, State University of Iowa, Iowa City, Iowa.

Burns, Eugene J., B.S., Biology, Chemistry. Junior Scientist, Research Laboratory, National Adhesive Corporation, Plainfield, N. J.

Burrington, John Darwin, M.S., Biology. U. S. Naval Officer, New York, N. Y.

Cader, Gordon, M.D., Physiology. Fellow in Medicine, Johns Hopkins Medical School, Baltimore, Md.

Cass, Leo J., M.D., Tuberculosis. Cambridge Tuberculosis Sanitarium, Cambridge, Mass.

Chasen, William H., M.D., Arthritis. Chief, Arthritis Clinic, Veterans Administration Hospital, Boston, Mass.

Child, George P., M.D., Pharmacology, Medicine. Director of Pharmacology, White Laboratory Inc., Kenilworth, N. J.

Cobb, Boughton, B.S., The Pteridophyta. Business Manufacturing Textiles, Beacon Manufacturing Company, New York, N. Y.

Coleman, F. C., M.D., Medicine, Biology. Pathologist, Mercy Hospital, Des Moines, Iowa.

Console, A. Dale, M.D., Therapeutics. Medical Director, Squibb Institute, New Brunswick, N. J.

Cope, Freeman W., B.A., Biology. Medical Student, Johns Hopkins University, Baltimore, Md.

Coulson, Roland A., Ph.D., Biochemistry. Associate Professor of Biochemistry, Louisiana State University Medical School, New Orleans, La.

Creutz, Edward Chester, Ph.D., Nuclear Physics. Head, Department of Physics and Director, Nuclear Research Center, Carnegie Institute of Technology, Pittsburgh, Pa.

Cross, Chester E., Ph.D., Biology, Meteorology. Research Professor, Cranberry Experiment Station, East Wareham, Mass.

Curby, William A., M.S., Medicine, Dentistry, Re-

search Co-ordinator, Tufts College Cleft Palate Institute, Boston, Mass.

Cuttle, Tracy D., M.D., Internal Medicine. Chief of Medicine, U. S. Naval Hospital, Yokosuka, Japan.

D'Angio, Claude J., B.A., Chemistry, Odor Research. Assistant Director of Research, Airkem Inc., New York, N. Y.

Deiss, William P., M.D., Internal Medicine. Research Associate, University Hospitals, Madison, Wis.

Deming, Quentin Burritt, M.D., Internal Medicine. Assistant Professor of Medicine, Columbia University, New York, N. Y.

DeNavarre, Maison G., Ph.C., Cosmetics, Antibiotics. Vice President, Manufacturing and Research, Cosmetic Laboratories Inc., Detroit, Mich.

Dente, Gino A., M.D., Anesthesiology, Medicine. Clinical Instructor in Anesthesia, University of Vermont, Burlington, Vt.

DeWolf, Gordon Parker, Jr., M.Sc., Taxonomic Botany. Graduate Assistant, Bailey Hortorium, Mann Library, Cornell University, Ithaca, N. Y.

Dolnick, Ethel Helen, B.A., Animal Skin. Biological Microanalyst, U.S. Department of Agriculture, Beltsville, Md.

Doorbar, Ruth Rae, B.A., Psychology. Staff Psychologist, New Jersey Diagnostic Center, Menlo Park, N. J.

Dun, Fwu Tamg, Ph.D., Neurophysiology. Associate Professor of Physiology, Kirksville College of Osteopathy and Surgery, Kirksville, Mo.

Eckenhoff, James Edward, M.D., Anesthesiology. Associate Professor of Anesthesiology in Surgery, Hospital of University of Pennsylvania, Philadelphia, Pa.

Elkin, Bernard P., B.S., Cancer Research Mechanical Apparatus. Research Director, Mechanical Research Foundation, Elmhurst, N.Y.

Ellis, Francis Cutler, B.S., Electrolytic Condition of the Human Body. President Ellis Research Laboratories, Chicago, Ill.

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